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A MODEL TO SUPPORT INFORMATION EXCHANGE BETWEEN ORGANIZATIONS WITH DIFFERENT RHYTHMS

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ABSTRACT

Emergency response operations are complex and busy. Many times military organizations, along with civil agencies, work to rescue people and bring relief. In order to do that efficiently, command centers must receive and send information in a timely manner. However, the information exchange between command centers often does not run as smoothly as it should. Sometimes the information does not arrive. On other occasions, it does arrive but not when it is needed most. In other cases, it arrives too often, causing information overload. Some of these problems occur due to differences in the timing of each organization, what we call here different organizational rhythms.

We are introducing a model, which borrows several basic concepts from music theory, for coordinating the information exchange process in emergency response operations. This research creates a model that can dictate critical times for exchanging information in these operations and, if needed, can also create a synchronization between two organizations. The findings from this research will support the creation of computerized agents to assist online information exchange between organizations with different rhythms.

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So, I dedicate my work to all of you, who are responsible for me being able to get there.

1 Introduction

Natural disasters frequently occur singularly and unexpectedly (Salmon et al., 2011). Even if there is some preparedness, emergency response in natural disaster management is complex and busy. There is a tendency worldwide to use military forces, especially as first responders, to aid the affected population (Weeks, 2007) in Emergency Response Operations (ERO). This happens due to their preparedness and mobility (Hofmann & Hudson, 2009). However, successful operations need not only a rapid response but also effective coordination among participating organizations (Seppänen et al., 2013). The coordination required in matching different organizational rhythms is the main topic of this work.

Due to the diversity of the organizations involved, many coordination problems arise (Koppenjan & Klijn, 2004; Jones & Lichtenstein, 2008; Passos, 2013; Alexander, 1998). Integrating different military branches into a coordinated force is difficult (Pramanik, 2015; Passos, 2013), but currently, there is an understanding that integration takes advantage of the branches' different skills and optimizes resources. However, "each Service maintains its culture, heritage, and ways of engaging in battle" (Military Leadership Diversity Commission, 2011, p.15).

People in charge of emergency response operations tend to see military branches as, in general, cohesive. However, in practice and under pressure, the differences between the branches of the Armed Forces are greater than expected (Zaw & Lim, 2017). These differences take part in each branch having less information than they need to make decisions when working in joint operations.

A significant amount of information needs to be exchanged among the participant organizations (Joint Publication 3-08, 2016). This sharing is crucial in order to achieve a desirable level of Situational Awareness (SA) (Endsley & Garland, 2000; Chmielewski, 2009).

Many times, participant organizations have enough information for making decisions, but with problems of timing and lack of assured quality. Finding critical information and its source during an operation is time-consuming and hinders the response activities (Seppänen, 2015). In many cases, there is information overload, since peripheral and passive information tends to arrive in droves.

It is established that organizations have their own pace and rhythm (Schein, 2010; Brown & Eisenhardt, 1998). There are temporal patterns in their work. Individuals and groups tend to adapt their tasks to fit the patterns or rhythms of their organization. In addition, organizations' norms have a tendency to incorporate organizational values. For example, if the preferred pace is fast or slow, or if decision makers prefer speed over quality (Blount et al., 2005). In this sense, there is a link between organizational rhythm and the performance of an organization (Rogers, 1994).

1.1 Motivation

This project started due to a major natural disaster in Brazil at Rio de Janeiro State, in the mountainous region north of Rio de Janeiro city, in 2011 (Busch & Amorim, 2011). Although the Brazilian Army is responsible for responding to emergencies, in that flood and landslide disaster, the Navy acted as a first responder. It happened due to their proximity to the places that were hit. However, all Brazilian Armed Forces were involved in collaboration with Civil Defense (the Brazilian equivalent to FEMA). The municipality had no means to deal with a disaster of such large proportions, with almost 1,000 deaths (United Nations, 2011).

There was also extensive flooding of the Madeira River in the North Region in 2014 and mudslides in the state of Minas Gerais in 2015. However, due to the proportions of the Serrana Region Disaster, it reshaped the way the armed forces act in ERO. Many lessons were learned (Bjerge et al., 2016), and it improved Brazil's preparedness for this kind of emergency (Júnior, 2016). The national management disaster system was reorganized under the Federal Law No. 12.608 of April 10, (Brazilian Federal Law 12.608, 2012), which defines the obligations of the federal, state, and local administrations. In fact, after this disaster, it created a more clear definition of roles and responsibilities in ERO. Further, coordination methods were improved. However, the different rhythms of each military branch were still hidden in the information exchange during the operations.

In studying the ERO of that disaster, it is clear the many coordination problems that appear in the reports. In addition, the lessons learned also emphasized that these coordination problems occurred mainly due to the following factors: uncertainties in the environment, temporal problems due to the limited duration of the operation, human factor problems in the relationship between organizations, and the attributes of different cultures in the organizations involved in the operation (Passos, 2013). In order to study this ERO, there was an attempt to put all the events, actions, and decisions into a timeline. However, this was very difficult to do because, even with all the information available, the temporal differences in the information were hard to deal with. We noticed different granularities in time. The precision of registries varied from seconds to days; in addition, they referred to events with different durations, which made it even more challenging to create a timeline.

We noted that the cultural differences were reflected in the information that was reported. Semantics, time, and rhythm, all seem to have an impact on how the organizations understand each other. These barriers can be tackled with the aid of information technology. However, in order to develop solutions, the organization's rhythm has to be better understood first.

1.2 Aim and Scope

We address the following research question: How can we implement synchronization of different organizational rhythms to support information exchange between civil and military organizations in emergence response coordination?

We use a design science approach, focusing on solving a problem identified in the literature (Peffers et al. 2007) and music polyrhythm as inspiration to create the model. Thus, this research aims to develop a model that aids information exchange between organizations with different rhythms.

The first necessary step to deal with different information exchange rhythms is to define each organization's work pace. Second, identify the best moments for exchanging information, then determine the overlap for the most timely exchange of information that is interesting for each branch as well. In such a solution, each organization would send and receive information in their own rhythm. In addition, the model is adjustable for different rhythms by a number of factors. In fact, the model makes the rhythm explicit that, to some extent, is already present in each military branch. The model uses basic concepts of rhythm from music theory, mainly polyrhythms and Son Clave. Polyrhythm in music is the rhythm composed by different rhythms played simultaneously and Son Clave is a specific type of polyrhythm known by some uniqueness properties and shared roots in Afro-Cuban-Brazilian rhythms.

The focus is on the information exchange between military branches that had had problems with different time perspectives and different modus operandi rhythms in the past, even when they were willing to share information. In addition, we present a clear explanation of how the rhythms are different and how those differences can be overcome using the model to address the problems of exchanging information under pressure.

The organizational rhythm tends to permeate the patterns and repetitions in the way that information is exchanged. The model is designed to create compatibility between different organizations with different rhythms. This is important because, in ERO, it is common to deal with passive information gathering (Militello et al., 2007), peripheral information (Maglio & Campbell, 2000), or unsolicited information. It was found that it is easier for a military branch to deal with these types of information if they are exchanged in a rhythm that is similar to their own.

This distinction of passive information gathering is made here because it is different from active information gathering (Ramirez et al., 2002), in which the military branches expect to receive the information that they need as soon as possible. Passive and peripheral information are more likely to be used if they are sent or received within a rhythm that is similar to that particular organization. In other words, if information arrives on time or, as we propose in our model, on a time adapted to the receivers' organizational culture, it might be more useful. At least the information should be received at expected intervals.

The proposed model is a mediator, creating compatible rhythms for each branch, or even for all the branches, at the same time. In other words, when one branch sends information to another, the mediator will intercept, hold it, and send the information at the key moment to the receiving branch.

The model is general enough to permit other uses. For example, it could be used as a starting point to define rhythm in other organizations that are not necessarily related to ERO. Aside from the academic contributions gained from the research results itself, it is possible to define temporal problems in information exchange. We expect that the current work will create a solid basis for research to be developed.

1.3 Significance of the Study

Time is one aspect of emergency response scenarios or situations, and it is important when exchanging information because it is part of evaluating possibilities in order to execute actions. When organizations have different cultures, they tend to have different information rhythms and flows. This can lead to some communication barriers. This does not imply that an organization never gets the information it needs, but it does mean that sometimes differences in rhythm might increase uncertainty in the environment, reducing Situational Awareness (SA) (Endsley & Garland, 2000; Chmielewski, 2009). The different rhythms can increase the possibility of unintended decisions leading to undesirable outcomes.

In this dissertation, we started looking into how the military deals with information exchange in disaster relief operations. We created a classification of five problem types in information exchange and solved with our model the types I, II, and III. We defined the concept of key moments, which are the best moments for information exchange. Thus, we developed a model that helps different military branches know key moments of communication, so that exchange happens in a timely way and develops in line with each branches' culture. We believe that we can use this model for two immediate purposes. First, coordinate passive information in order to improve SA. Thus, one immediate benefit could be reducing information whose immediate relevance remains unknown. Second and most importantly, help to put information in a timeline for debriefing or lesson learned process.

Our model is capable of preventing the loss of information over time. In addition, the model uses information exchange rhythms that are similar to what each branch is used to. One contribution of this research is to explain the problem of exchange information in depth, bringing to light details and nuances of information exchange that is often hidden behind other coordination problems in ERO.

The findings from this research will support the creation of computerized agents to assist information exchange between agents with different organizational rhythms. We expect that a unified view of the whole operation — and a view for each branch— can improve knowledge and use of that information when applying our model, using key moments for information exchange.

This work is organized into six chapters. In this chapter, we briefly introduced military actions in ERO and the problem of different rhythms in information exchange.

Chapter 2 is focused on rhythms and how rhythm is understood by organizations. In addition, it presents the music theory for polyrhythm and Son Clave, specifically looking into the music theory needed for building our model. Chapter 3 describes the military culture, models and information. Chapter 4 presents the mini-case study and problems in information exchange in ERO. Chapter 5 describes in depth the model, its functioning, verification, and empirical validation. Finally, in chapter 6, our contribution is stated, proposals for future work are made, and our conclusions are presented.

2 It Is All About Rhythm

The concept of rhythm concept has been used in different disciplines. However, a general theory of rhythm has not yet been formulated (Fraisse, 1982). This concept (Handel, 1984) has been variously applied to corporeal, historical, chronological, and philosophical contexts. It also encompasses "the multiplicity of noises, [and] murmurs" in everyday life, as studied by Lefebvre (2013). Even though many understandings of rhythm exist, this concept can be generally understood as patterns of visual, aural, and temporal rhythms.

In the contexts of storytelling, poetry, and theater, narrative rhythm uses such elements as pace, tone, and voice to express energy and even mood (Freer, 2015). Narratives are also used in decision making processes and, by extension, in disciplines and institutions related to command and control, such as the use of the double-Freytag triangle (Rao, 2011) in military schools.

Rhythmic alternations between light and shadow, sound and silence, movement, and rest, for example, create many patterns around us. Freer (Freer, 2015) argues that rhythm exposes the regularity that occurs in the irregularity. For organizational theory, rhythm characterizes the way that organizations work and execute daily tasks (Pina e Cunha, 2008).

Rhythm is also widely studied in music (Wittlich, 1977; Battaglia & McNaughton, 2011; Krumhansl, 2000). Rhythms occur in the brain (Battaglia & McNaughton, 2011) or in the motor behavior of a person (Buchanan & Ryu, 2006). Many studies show that our brain has rhythm and synchronizes with the environment (Thaut et al., 2008) while thinking in order to understand and execute its tasks (Bluedorn, 2002).

This cross-sectional understanding of rhythm serves as a basis for solving the problems described in Chapter 4. Additionally, in this chapter, we will develop further the understanding of rhythm as related to music theory because rhythms carry information in terms of music, harmony and melody.

2.1 Organizational Rhythm

Rhythm is part of what defines or differentiates organizations. In fact, it is established that organizations have their own pace and rhythm (Schein, 2010; Brown & Eisenhardt, 1998). There are temporal patterns in the work of organizations. Individuals and groups tend to adapt their tasks to fit in with those patterns or rhythms of the organization. In addition, temporal norms have a tendency to explain the organizational values. For example, if the preferred pace is fast or slow, or if speed is preferred over quality for decision makers (Blount et al., 2005). Clark (1985) and Gersick (1994) identified three main types of rhythms in organizations and inter-organizations: the chronological rhythms, based on calendar; the event-based rhythm, based on temporal milestones toward an objective and the repercussion-based rhythm, that is based on repercussions of the temporal milestones, in which based on environment activities might be replanned.

For Jones and Lichtenstein (2008), chronological rhythm uses techniques such as deadlines, agreements, and timelines that define and coordinate who does what and when.

These mechanisms provide a rigid time frame, which helps to coordinate the team and control the process. The event-base rhythm deals with goals and milestones. Environment uncertainty is reduced by showing completed milestones toward a goal. The milestones work as a coordination tool once clearly defined what has to be accomplished. Repercussion-based rhythm happens when joint activities are synchronized by unifying the temporal dynamic of each organization. This rhythm reverberates, in less or more proportions, to all participating organizations.

Pina and Cunha (2008) also emphasize that rhythm is part of the organizational culture and helps to define and differentiate organizations. They categorize types of organizations by their intrinsic times: hyper-competitive, pressed, pulsed, and out-of-time. In this sense, there is a relation between the organizational rhythm and the performance of the organization (Rogers, 1994). In the literature, there is work exploring how an organization paces itself according to its external environment (Eisenhardt, 1989) or creates new rhythms from external interactions (Perlow, 1999). Jackson et al. (2011) explored organizational rhythms to explain part of the collaboration in scientific work.

2.2 Entrainment and organizations

An important phenomenon occurring in and around rhythmic patterns is *entrainment* (Rogers, 1994). Christian Huygens formulated the law of entrainment from his observation of two clock synchronization. His law has two components: (1) two or more independent rhythm processes, and (2) an interaction between those processes or oscillations must occur (Vuust et al., 2014). This phenomenon has been studied not only in mechanical systems but also in biological systems. Entrainment also occurs in many systems in the human body and is present in neuronal brain waves (Thaut et al., 2008) and circadian systems (Vuust & Witek, 2014).

A clear entrainment definition is presented by Jones as "…a process involving adaptive synchrony of internal attending oscillators with an external event" (Jones, 2008, p.128). The perception of temporal regularity of sounds is also part of entrainment in musical contexts (Honing et al., 2014). Clayton et al. (2005) define entrainment as an ability that human beings have to synchronize with the external rhythm. For example, the rhythm in music can be followed by clapping one's hands. Rhythmic entrainment also refers to the ability to perceive the pulse that marks equally spaced points in music or a sequence of auditory stimuli, and to then align motor actions to that pulse or beat (Large, 2008).

Many works that deal with rhythm concentrate their efforts on adaptive oscillatory models that use phases and periods for tracking and synchronization (Sethares, 2007; Saltzman & Byrd, 2000; McAuley, 1995). It is argued that one of the most sophisticated forms of synchronization involves beat-based predictive timing in which the inner beat aligns to an external time-giver (Fitch, 2013). Although patterns and synchronization play a major role in entrainment, patterns usually do not overlap but instead tend to keep a consistent relationship with each other (Bluedorn, 2002).

Ancona and Chong (1992) created an organizational framework that incorporates time in order to explain organizational behavior. In her work, the use of temporal patterns is related to entrainment. Two different rhythms can interact and adjust to each other. In this sense, a better definition for the term is “the adjustment of the pace, cycle, and rhythm of one activity to match that of another” (Ancona & Chong, 1996, p. 251).

Ancona and Chong (1996) divide organizational rhythm entrainment into three degrees: Tempo, Synchronic, and Harmonic. Tempo is the entrainment of pace, such as a factory worker doing their job at the same rate as other workers. Synchronic entrainment is the meshing of rhythm and pace and involves an evaluation or influencing period. Harmonic entrainment is the meshing of two behaviors, such as perceived by an observer in a mentor-mentee relationship (Ancona & Chong, 1996, Pérez-Nordtvedt et al., 2008).

Using Ancona’s framework (Ancona & Chong, 1992; 1996), Pérez-Nordtvedt et al. (2008) created a conceptual model that explores the different timing and cycles in an enterprise. The synchronization of an organization with an external one increases predictability and reduces uncertainty. Shi and Prescot (2012) used a similar idea of extra-entrainment and intra-entrainment to enhance organizations’ performance.

Music is event-centered, and events are placed at appropriate times. Other musical cues might contribute to generate expectations and are used to cause entrainment. Music has already been explored as a way of understanding organizational change (Magala et al., 2007; Nguyen, 2010). Unifying entrainment and music, Nyguen (2010) created a framework linking music theory to concepts and dynamics for organizational change, as seen in Figure 2-1.

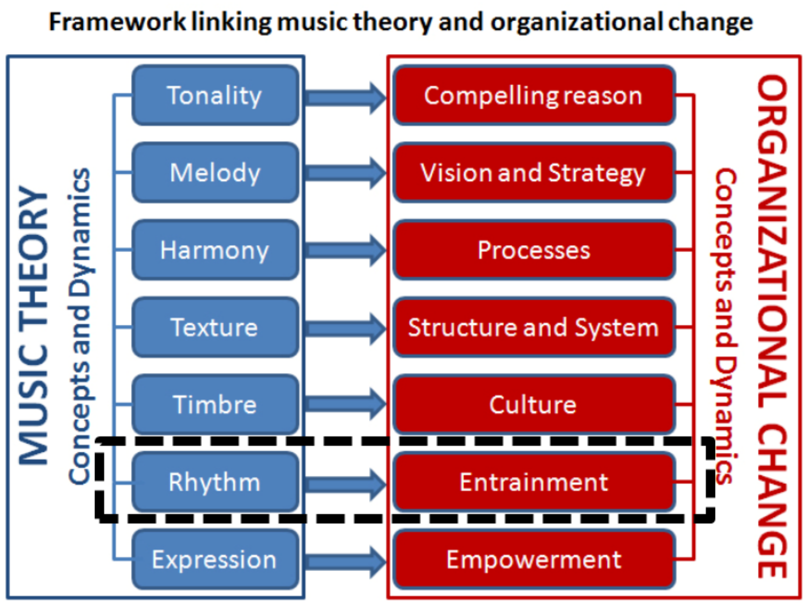


Figure 2-1. Modified from Nguyen (2010).

The music concepts presented in Figure 2-1 are considered essential for organizational change, but they are also crucial for many other processes of organizations as a whole. In addition, the rhythm is associated with the entrainment in the organizations, as can be seen inside the dashed line in Figure 2.1.

As rhythm is related to entrainment (Ancona, 2015; Ancona & Chong, 1996; Ancona & Chong, 1999; and Khanna, 2018), organizational research also uses a temporal lens (Brunelle, 2017). Although some works about organizational theory created accurate and extensible temporal conceptual ideas, they did not explore rhythm nor how synchronization can be used for information exchange.

2.3 Synchronization

One of the main kinds of rhythmic entrainment happens with music (McNeill, 1995). For Hachinski & Hachinski (1994), music is able to trigger hierarchical cooperation between the two hemispheres of the brain, and this cooperation helps in the synchronization of many elements. It is argued that one of the most sophisticated forms of synchronization involves beat-based predictive timing, in which the inner beat aligns with an external time-giver (Fitch, 2013).

It is in music theory that some aspects and nuances of rhythm can be scrutinized (Sethares, 2007), which may support the application of the use of rhythm in solutions for the problem of information exchange. One of the most elaborated forms of communication is human musical interaction (Large, 2008).

Although it could be interesting to deepen the investigation of music entrainment among different participants, this does not facilitate a computational approach to information exchange between organizations. Moreover, exponent works such as Clayton's (2005) do not explore entrainment in depth between two or more participants. In fact, a feasible model should be simple, requiring few changes for implementation. Thus, this dissertation will demonstrate only the feasibility of applying music abstraction to the processes of information exchange.

Although different rhythms can entrain in unison, the most common form is hierarchical or polyrhythmic. For example, musicians playing together demonstrate different degrees of entrainment during a piece. This principle holds true for organizations, as well. Therefore, we created a framework based on Ancona's (1996) tripartite model that translates rhythm to an organizational structure.

2.4 Framework

At this point, it is already established that activities occur at different times in different organizations. Rhythm is present in organizational communications, though it may not be immediately evident. We thus create a functional framework for this study by relating the elements of rhythm to the elements in organizational communications. In Figure 2-1 the dashed line, highlights the rhythm. In Figure 2-2, we explore the rhythm introducing a framework that relates elements of musical rhythm to the elements of organizational rhythm.

Music concepts do not translate straightforwardly to other fields (Ancona & Chong, 1996). Music concepts must be appropriately adapted in order to create a model that works in different environments. The beat or pulse in music is related to units of time, such as seconds, minutes, and so on. Tempo/Pace is related to pace, from fast to slow, and is measured in numeric values. In addition, our framework explicitly includes arrangement and repetition, which are not often mentioned in traditional studies of Western music that involve rhythm elements (Toussaint, 2015).

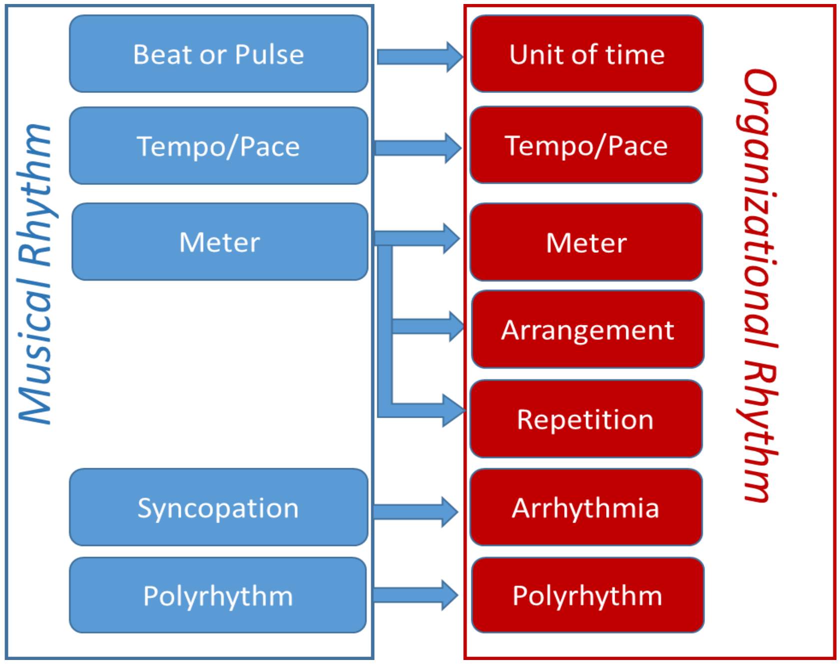


Figure 2-2. Relationship between Musical Rhythm and Organizational Rhythm.

The literature on organizational theory (Khanna, 2018) relates the concept of arrhythmia to syncopation. While syncopation might be desired (Hoesl & Senn, 2018) in music, its dissonance might not be considered a valuable characteristic for an organization as it is in music. Therefore, syncopation is not explored in this work. We focus on polyrhythm because our main interest is in the different rhythms that occur during the exchange of information.

Now we have to outline a conceptual difference between musical notes and information units regarding duration. In our abstraction, notes are equivalent to sentences that express events or actions. Each information unit is characterized by a time duration. The organizational rhythm is based on operations.

2.5 Musical Rhythm

As already stated, music is able to present temporal information in a very detailed way (Albert & Bell, 2002). Music may be decomposed into such fundamental elements as rhythm, pitch, dynamics and expression, form and structure, timbre and texture. Despite the difficulty of defining these elements, rhythm is often present in the literature we reviewed. However, in music theory, rhythm is separated from other elements for didactic purposes.

Rhythm is perceived as instinctive. For example, people often move to the beat of music without being taught, and even children and parrots can sense rhythm in music (Patel & Iversen, 2014). According to Toussaint's definition, "… it is more accurate to characterize rhythm as a manifestation of a process that emerges from the amalgamation of a physical signal with perceptual and cognitive structures of the mind" (Toussaint & Dhabi, 2013, p.6).

For musicians, rhythm can be defined as the regular, repeated pattern of movement or sound. In other words, rhythm is the relationship between the parts, which make them equally spaced and regular or unequally spaced and syncopated (Garland & Kahn, 1994). Rhythm is a central part of music structure, organizing musical patterns in time. Some argue that rhythms represent a set of sequential events organized in trees that aggregates in a hierarchical way (Longuet-Higgins & Lee, 1982).

Musical rhythm can be perceived as a sequence formed by the rate at which a metronome ticks (e.g., four times per second). When the ticks are less frequent than two times per second, though, say at intervals of three seconds, the sounds are no longer perceived as a sequence, and each sound impulse remains an isolated perceptual event

(Warren, 2013). Similar results occur with low-tempo music. Music, like a spoken sentence, is only recognizable as such when its rhythmic patterns and phrases are presented at an optimal speed that allows them to be recognized as a perceptual unity.

All rhythms relate to time and space in a certain way. According to Hébert (2011) three characteristics define a rhythm: a segmentation into units, an arrangement, and a seriation. However, rhythm is known as the temporal dimension of music structure (Large, 2010), determining at what point in time a particular note in a sequence is played, for how long it is played, and how much stress this note will get. It is also argued that variations in music rhythms are embedded in cultural environments.

In music, rhythm usually occurs at a metric level, using a pulse or a beat as a unit of time. Rhythm has three aspects: "pulse" (beat, tactus, tick of clock, drumbeat), accent, and meter. People who tap their feet to the music are "keeping the beat" by following the music's structural rhythmic pulse.

2.5.1 Elements of Musical Rhythm

Rhythm is based on four basic elements: units of time, frequency of time units, groups of beats with accents, and rhythmic patterns that present sequences over intervals of time. In this work, we use the most relevant music terms and define them as follows:

- Beat or Pulse – According to Sethares (2007), the beat is "… the steady foot-tapping pulse that drives the music forward and provides the temporal framework on which the composition rests." Beat is the regular pattern of rhythmic stress in music, while pulse refers to the frequency of the beat. An isochronic pulse works as a clock and provides some innate regularity and a sense or prediction of a temporal event. Inside a pulse, we are able to identify discrete rhythmic categories and a temporal continuum (Honing, 2002).

- Meter – Meters are the cyclical time units above isochronous pulse streams. That Meter, or measure (London, 2002), involves beat perception and some kind of anticipation of the next beat. Meter and pulses together can be defined as rhythm (Arom et al., 2004). The rhythm is notated in two main different ways:

  - Western and classical rhythms – the rhythm is explicit by time signature (Toussaint, 2015). A time signature consists of two numbers, stacked one on top of the other, where the top number represents the number of beats per measure, and the bottom number represents the note value for each beat (Biamonte, 2014). There are three kinds of meters, metrics or measure: regular, formed by two, three, or four constant beats; irregular; and complex (London, 2002), with large pulses and different sizes. For London (2004) musical meter is a cyclical repetition of patterns of attentional energy focused by the listener on specific moments within a given meter. Each measure is set off from those adjoining it by bar lines. In a measure, a whole note lasts four beats, while one beat indicates one quarter note. Most compositions are based on quarter notes. A metronome measures the duration of notes, and composers usually provide an indication of the speed at the beginning of pieces or parts of pieces but do not indicate note duration. However, notes can be aggregated into groups, and groups into phrases and songs, or whole musical pieces.

- Non-Western and African rhythms - the notation is given by timelines (Temperley, 2000), in which the repetition is extensively used (Arom et al., 2004). Timelines will be further explored.

- Duration – In Western music, note duration can be defined as a set of ratios with small integers that aggregate themselves into larger ones (Demaine et al., 2009). The duration of notes does not have a clear time value in some non-Western music. Therefore, for example, a beat can have a relative duration in the same manner that notes do (Arom, 1989).

- Tempo **–** Another concept related to rhythm is tempo**.** Tempo can be defined as the speed or pace of something (Tempo, n.d.). Tempo can also be expressed verbally with such words as Presto, Allegro, or Largo (Garland & Kahn, 1994). Also, Handel (1993) showed that the same rhythm presented at different tempos will not, as a general rule, be recognized as the same rhythm. Using a narrative approach, Rao (2011) uses tempo to mean not only rhythm but also emotions, energy and beliefs. For Gooch (1997) Tempo is "the Rhythm or rate of activity on operations, relative to the enemy." (p. 11). The word pace can be used to indicate speed, whereas in some works rhythm is more related to the whole general flow of the value of the beat is given by composers at the beginning of musical pieces or sections as an indication of the tempo. In musical pieces, tempo is the speed of the beat, using a unit called Beats Per Minute (BPM) and measured with an instrument called a metronome. For example, a tempo of 120 BPM will have 120 beats in one minute.

- Note – A note is a tone placed in a particular temporal context (Loy, 2006). The note is the basic unit of a melody. Notes are composed of pitch and time duration. The sound of the musical part is called a note while the silent part is called a rest, and each note or rest has durations that start (onset) and end (offset). Notes can be categorized as harmonic or percussive. Harmonic notes are those that humans would categorize as musical notes because they have a well-defined pitch and are harmonically related (Klapuri, 2006). On the other hand, percussive notes do not have a defined pitch.

- Rest – In music, rest or silence indicates a unit of silence. In our model, there is a rest or silence, that is equivalent to the time duration of each slot. A rest means there is no information to be sent or received in a given slot. We define silence as the non-existence of information in a given slot.
- Onset – In music, onsets are sounded pulses or the start of a sounded note, harmonic or percussive.

All the cited rhythm characteristics explained above takes part in the construction of the working model presented in this dissertation. These characteristics often are also present in rhythm representations (Akhtaruzzaman, 2008). These representations are used to study rhythm structures.

2.5.2 Representations

Two notations are often used to illustrate rhythms. One is the circle notation presented in Figure 2.3 in which each pulse with sound (onset) is represented by a black dot in a circle, and each pulse with silent notes (offset) is represented as an empty dot. The duration pattern notation (Breslauer, 1988), or inter-onset interval structure, denotes how many empty dots exist between one full dot and the next.

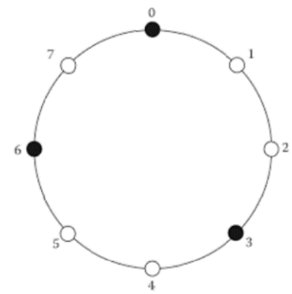


Figure 2-3. Circle Notation.

Amiot and Sethares (2011) argue that it is also possible to express rhythm as a linear combination of columns of scale matrices. A simple representation of rhythm is presented in the Time Unit Box System (TUBS) notation. This notation has a row of boxes and each box represents equal lengths of musical time. TUBS notation is also useful for making explicit the relationships of complex rhythms. For example, the TUBS notation in Figure 2-4 presents the rhythms of two different organizations, the Army and Navy in a 3 by 2 polyrhythm. Each box represents a fixed time period. The beats are represented by the number 1 and the rests by the number 0. Each organization has a given number of beats. The Army is represented by 3 beats for every 6 periods of time and the Navy two beats for the same six periods of time. The number is six because the Army counts for 3, and Navy counts for 3. Thus, the groups of periods of time are the result of the multiplication of 3 by 2 (Magadini, 1995). The gray and the white mark groups of six periods of time. In Figure 2-4, there are four groups of six. The red circles mean moments in which both organizations have beats. These are the key moments used in our model.

Figure 2-4. Example of polyrhythm in TUBS notation.

2.5.3 Complex Musical Rhythms

Rhythm organizes time (Amiot & Sethares, 2011), and frequently the metrics of beat and rhythm are called the “building blocks” of rhythm processing (Cope et al., 2015). In some styles of music, the meter may be acoustically represented only weakly in the music itself, resulting in complex rhythms. The complexity is usually determined by the difficulty in the execution or recognition of musical metrics or beats in a piece (Povel & Essens, 1985).

Human beings are able to synchronize their own internal rhythms with simple and complex external rhythms (Large et al., 2002). Many complex musical rhythms present such characteristics as groove, syncopation, and polyrhythm. Groove keeps interest in a music (Madison, 2006) and is detectable via a “knowledge shared between musicians” (Zbikowski, 2004, p. 272).

Groove is often described with a certain degree of subjectivity, and it stimulates dance and movement (Lamb, 2014; Pressing, 2002). Therefore, groove relates to the psychological aspect of entrainment in musical rhythms (Madison, 2006). Groove may also be expressed in a numeric sequence of polyrhythms and syncopation (Hoesl & Senn, 2018), which represent the complexity that can be achieved in temporal prediction (Honing et al., 2015).

Syncopation is a displaced beat in which the accent occurs in an unexpected place, e.g., a strong beat occurs where a weak one was expected. In other words, it is when something happens outside of the rhythm metric and shifts the emphasis of the music in an unexpected way (Gómez et al., 2005). In this case, some accents occur in the weaker part of the metrics, which is the opposite of the rhythm’s systematic structure. In this sense, syncopation can be defined as when an unexpected event occurs in the rhythmic music meter that changes the part of music in such a way that results in an unexpected reaction (Song, 2014).

Syncopation and polyrhythms are rhythmic forms that produce groove. While syncopation usually works in one-time signature, polyrhythms present more than one. Nevertheless, many rhythms in a polyrhythm may be syncopated. The polyrhythm abstraction can be used to visualize information exchange in ERO.

2.5.4 Polyrhythm

Warren and Warren (1970) define polyrhythm as the “two or more basic rhythmic patterns going on at the same time” (p. 31). In other words, polyrhythm is the occurrence of two or more rhythms concurrently (Sethares, 2007). A performance produces different rhythms at the same time (Galvão, 2014). The rhythms might be similar or different. While some scholars make a distinction between polyrhythm, cross-rhythm, and polymeter, in this work, we use the word polyrhythm without making such a distinction.

Researchers have long studied the perception and performance of polyrhythms since they involve many difficulties regarding cognition of music and movement control. Polyrhythms require the production of simultaneous and incompatible movement sequences (Pressing, 1993). Polyrhythms are recognized as a language in musicians’ brains when performing (Vuust et al., 2006). In polyrhythms, different meters are often executed simultaneously. However, even when two rhythms have the same meter, one might shift in accent or beat position, creating a polyrhythm.

Drums have been used by the military since antiquity not only for keeping marching rhythm but also as a form of communication (Gleick, 2012; Norris, 2012; Sterling, 2008). Drums play a major role in polyrhythms (Vuust & Roepstorff, 2008) and call-response communications in music. The parallel between the use of drums and communication is, in fact, a homology due to shared roots between music and language (Arom et al., 2004; Nattiez, 1990).

Among the most significant differences between Western and Non-Western music, including African, Balinese, and Japanese music, is the use of more complex rhythms and polyrhythms to which this research attends. Clave patterns are rooted in African music instead of classical Western music (Getz et al., 2014). The latter usually presents two, three or four different rhythms at the same time. Therefore, the rhythm pattern of the Clave allows for the modeling of several simultaneous rhythms in Joint Operations Rhythm.

The music of other cultures, such as Balinese Gamelan music and Indian Talas music, also has interesting polyrhythms (Handel, 1984). However, due to their complexity, these rhythms were not considered ideal for use in an initial model of rhythm for information exchange.

2.5.5 Rhythm Patterns, Timelines, and Clave

Although there is some discussion about the way that Western and African rhythms are compared (Munyaradzi & Zimidzi, 2012), it can be said that while Western music tends to have one main rhythm, or one main beat and key modulations, non-traditional rhythms such as African rhythms tend to have polyrhythms of 2, 3 or more rhythms at once (Munyaradzi & Zimidzi, 2012).

For McAuley (1995), rhythmic patterns tend not to be revealed all at once, since it takes time for patterns to be developed. Repeated rhythm patterns are called timelines (Demaine et al., 2009). In other words, timelines, also known as bell patterns (Agawu, 2006) or key patterns (Rahn, 1996), are rhythms that repeat many times in a piece of music.

A timeline is a well-known type of ostinato (Rahn, 1996), that repeats itself, exactly as the beginning, along with the music, and acts as a timekeeper and structuring device for musicians (Agawu, 2006; Toussaint & Dhabi, 2013). Specialization timelines are widespread and might be played in different instruments but are usually used in percussion to provide structure for composition and performance. In addition, timelines are temporal references for musicians (Kubik, 2010).

Usually, rhythm patterns or timelines are a set of 5 onsets spread over 12 or 16 beats or pulses (Arom, 1989). A classic example of timelines is the Clave. Meaning "key" in Spanish, the word Clave is also a wooden instrument (Vurkaç, 2012). In this work, we are using the timeline meaning of Clave. It has its origins in African-Cuban traditions (Toussaint, 2005), and is also known as 3 – 2 or 2 – 3. The Clave is used for a temporal organization (Marijan, 2018) in Afro, Cuban and Brazilian music.

Claves induce a strong sense of beat despite the presence of the offbeat of syncopation. The Son Clave and Rumba Clave are widely used in South American and particularly Afro-Cuban music but are also found in many forms of Western music, including pop, jazz, and electronic dance music. Furthermore, low complexity rhythms also follow the same 3-2 rhythmic pattern as the medium complexity rhythms, but with all syncopation removed, so that all onsets fall on strong beats (Matthews et al., 2019).

Clave rhythms are also considered examples of “ask and answer” or “call-response” relationships. That characteristic of speeches that is also found in some musical structures (Peñalosa, 2009). In a 3-2 timeline, for example, the three represent the question, and the two represent the answer. There are six timelines that use call-response and are considered essential rhythms around the world: Shiko, Soukous, Son, Gahu, Rumba, and Bossa Nova (Thul & Toussaint, 2008). All of them have in common 5 onsets over 16 pulses. The Son Clave has similarities with most of the other rhythms, making its rhythm feel familiar in many cultural contexts (Toussaint, 2002).

2.6 Son Clave

It is argued that the Son Clave serves as a framework for musical organization, informing and constraining rhythms. This rhythm is widespread, which may be unique (Toussaint, 2010). In addition, the Son Clave represents some of the most desirable measures in properties, such as maximum evenness, oddity, off-beatness, and different durations (Toussaint, 2004; 2017).

The Son Clave rhythm has been called different names in different places: the Bo Diddley beat in the United States, the Son Clave in Cuba, and the Kpanlogo bell pattern in Ghana (Peñalosa & Greenwood, 2009). Irrespective of its name, the Son Clave’s rhythmic pattern with inter-onset-intervals [3-3-4-2-4] is known worldwide (Toussaint, 2010).

2.6.1 Son Clave Properties

The Son Clave was chosen for this project because its flexibility allows it to accommodate our conceptual model. Toussaint argues that the Son Clave possesses several musicological properties that make it a “good rhythm” (Toussaint & Dhabi, 2013), including almost maximal evenness, rhythmic oddity, rhythm-shadow contour isomorphism, and gestalt despatialization. Interestingly, these properties are all mathematical in nature. It is possible, with mathematics, to explain this rhythm (Toussaint, 2005). The properties are defined as follows:

Maximum Evenness - This property is the distribution of onsets as regularly and evenly spread as possible. Thus, it gives some predictability and expectancy to a rhythm. According to Kubik (2008; 2010), this characteristic grants the music an interoperability in that even after propagation among cultures, its pattern cannot be altered without losing its evenness.

Rhythmic oddity - This concept was developed and named by Arom Sinha (1989) and explored in Chemillier and Truchet (2003), and it states that onsets are arranged in a circle, and each onset must be diametrically opposed to a pulse. As explained about oddity, “one cannot break the circle into two parts of equal length whatever the chosen breaking point. There is always one unit lacking on one side” (Chemillier & Truchet, 2003, p.1). It is also argued that the rhythmic oddity property applies if the rhythm does not contain two onsets partitioning the cycle into two half-cycles (Toussaint, 2016).

Rhythm-shadow Contour Isomorphism – This property distinguishes the Son Clave from all other timelines in evenness. Each rhythm has an implicit onset that can be perceived between the real onsets. The rhythm contour of a rhythm is the values resulting from adding 0, +1, -1 according to the number of changes in durations, equal, greater, or lesser of the sequential inter-onset values. Thus, the Son Clave = 3 3 4 2 4 contour is 0 +1 -1+1-1 (Toussaint, 2013). The shadow rhythm is found by the anterior spaces, if rotated, fits exactly the onset spaces. Further explanations can be found in Eyssette and Galligo (2012). The rhythm shadow of Son Clave has the same contour of Son Clave itself.

Metrical Dissonance – According to Krebs (1999), metrical dissonance refers to perceived variations in metrical structures, such as shifts or conflicts in a musical piece. Temporal changes in music can cause Gestalt Despatialization (McLachlan, 2000). Metrical dissonance is also present in syncopated structures. In terms of information flow, this property accounts for the element of surprise that might occur in information flow in music (Temperley, 2000; Jaeger & Levy, 2007).

Call and Response – This property is the repetition of two different parts, where the second is understood as a response to the first. In the Son Clave rhythm, the first three onset notes are answered by two subsequent notes. This response provides a sense of closure by generating a perception of temporary or permanent end-points within the call and response structure (Meyer, 1996). While the call and response property always seems to have closure, not all closures in music derive from this property (Thul & Toussaint, 2008).

2.6.2 Representations of Son Clave Pattern

In Figure 2-5, it is presented with different notations for the Son Clave rhythm. The notation in lines 5, 6, 7, and 8 inside the red ellipse are used interchangeably in this work. Line 5 denotes the TUBS notation (Time Unit Box System). Chor (2010) emphasizes that durations are not represented in this schema, only onsets. That characteristic is considered ideal for African rhythms because they tend to deal more with onset, crisp and precise position of the note, while Western traditional music, represented in lines 1, 2, 3 and 4, tends to deal more with note duration (Van der Merwe, 1989).

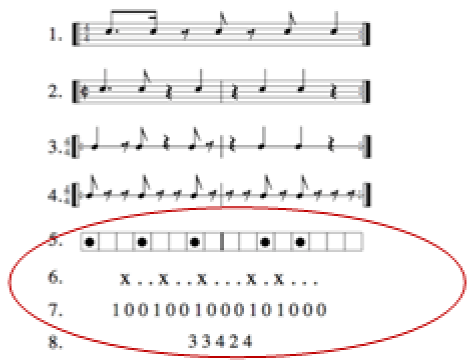


Figure 2-5. Son Clave representations (Toussaint, 2005).

Line 6 denotes the box notation in a running text, line 7 denotes binary notation, and line 8 denotes duration pattern (Breslauer, 1988), or inter-onset interval structure, which counts how many empty dots there are between full dots.

3 Background

From 2008 to 2010, the Ministry of Defense used two information systems developed by the Brazilian Navy, which interacted with during joint military exercises. In those days, some differences between the cultures of the different armed forces were observed. For example, “fast” for the Air Force seemed to have a different temporal meaning than what was understood by the Navy. Without quantifying, it seems to be faster for the former than for the latter. It was thought about investing in a thesaurus for the systems, and later integrating more semantic layers into them. Because of the high cost of these implementations, the idea was rejected. In a debriefing after an exercise, one Air Force pilot complained about the excessive amount of time that a Navy radio operator took to answer, causing him to lose the “target”.

Although the tactical forces dealt with these problems as lessons to be learned by their officers, this work designed a model that helped exchange information so that different time needs were made more “compatible,” and situations like those mentioned above could be improved. In addition, the model might assist in exploring rhythmic differences between the armed forces.

Although quite often, natural disasters are unpredictable, the response actions, and the information flow regarding those actions, might not be (Dworken, 1994; Hofmann & Hudson, 2009; Passos, 2013).

3.1 Disaster Response Operations and Military

It is undeniable that the armed forces have a crucial role as emergency responders in tasks such as search and rescue, wound transportations, and readiness of field hospitals, and they have saved many lives (Pramanik, 2015). Natural disaster response operations are considered humanitarian operations, triggered by people affected by a natural disaster, and cause the armed forces to coordinate their collaborative efforts with other organizations (Bastian et al., 2016).

It is always different in those situations for emergency response and humanitarian operations, because militaries have to cooperate with civilian authorities instead of having active control. Civil defense is responsible for these operations. However, due to their culture, it is relatively common for the military to use the command and control approach (Hofmann & Hudson, 2009), since techniques such as these are embedded into their culture (Hajjar, 2014).

The coordination of emergency response is challenging as it usually involves a high level of uncertainty and the necessity for rapid decision making, and response under temporal and resource constraints (Bjerge et al., 2016). A recent study coined the term *Samhandling*, which means interaction or cooperation, and specifically *Samhandling Under Risk* (SUR), meaning cooperation and how to cooperate or interact under unpredictable conditions (Torgersen, 2018). The *Samhandling* theory deals with a broader and more profound sense of collaboration or cooperation. The focus is on the relationships that occur between people or organizations, its needs, consequences, and even technology use. Thus, the complementarity, exchanges, different cultures, skills, and experiences, should be coordinated and goal-oriented.

The initial hours after a natural disaster are crucial and chaotic (Comfort et al., 2004). Those periods are vital for the search and rescue of survivors. Nonetheless, the role of volunteers many times is not well established, the local hospitals and logistic infrastructure are still being built, there is a lot of commotion in the media, and the relatives of the victims are looking for their loved ones. Therefore, there is too much noise around the information and communication.

It is hard to consider a civil defense intervention in major catastrophes without the assistance of the armed forces because the latter has adequate staff and equipment to deal with crisis situations (Bunker et al., 2015). There is a history of success to military disaster response, due to a greater operating capacity and an ability to quickly build up and respond to the disaster (Pollock & Coles, 2015). In fact, it is expected that military deployment optimizes all phases of disaster management.

Since it is common to use the armed forces in ERO, not surprisingly, the armed forces tend to use their knowledge — such as command and control, strategic, operational, and tactical expertise — to carry out their tasks. This use happens at national, regional, and local levels. Despite the cultural differences, it is widely known in the military that information exchange improves the quality of information and situational awareness in operations (Perry & Moffat, 2004). In order to set a rhythmic pattern, perhaps a more stable information exchange would be useful for the studies.

In such a complex environment as emergency response, there are very distinct groups. They have different backgrounds, different mindsets, and, therefore, different times to act and to distribute information among themselves. In other words, ERO has a less organized nature of responses than typical military operations.

According to the Brazilian National System of Protection and Civil Defense (SINPDEC), the Navy is assigned to coordinate harm reduction actions related to maritime and fluvial claims; to participate in rescuing shipwrecked persons; to support civil defense actions with personnel, material, and means of transportation; and to support disaster actions, with fluvial hospitals, i.e. floods occurring in the Amazon (*MD-33-1-01, Brazilian Instructions for the Use of the Armed Forces in support of Civil Defense*, 2015, p. 33; Lopes, 2016).

Typical hierarchical structures, such as military or governmental organizations, rely on a command and control mindset and framework to collect and present information to upper level decision-makers, and based on this information commands are given (Seppänen, 2015). Command and control systems applied to natural disaster environments usually account for communications systems; fast and complex contingency plans; central planning and steering capacity; and basic organization and communication structures for humanitarian aid organizations (Rosa, Bandeira & Leiras, 2014 ; Seppänen et al., 2013).

3.1.1 Military Culture and Information

The military deals with information exchange in a way that is unique to its culture. In general, military culture is based on a unique tradition-oriented by hierarchy and discipline. The military emphasizes ceremonies and missions, structure, and leadership (Wilson, 2008). Mission-focused and goal-oriented, military culture leads to easily followed rules and regulations, as well as readiness to carry out orders. In addition, military leaders expect loyalty from their subordinates and allies. Therefore, military men and women have a common language and develop a strong esprit de corps that indeed defines military organizational culture (Kier, 1995). Narratives are used to create a shared philosophy of decision making, and consequently for the disciplines related to command and control in military schools, for example, using the double-Freytag triangle (Rao & D'Andrea, 2007).

Notwithstanding some common structures, the military still faces challenges in information sharing. Due to the specificities of their missions and the work environment on sea, air, and land, the branches of the armed forces ended up creating different slight cultures within their branches, with different perceptions, approaches, and even separate military jargon. The differences are always noticeable, but it is common to try to find similarities. These are important due to the acknowledgment that, even before World War II, some of the branches might operate together (Sirius, 1933).

Armed forces often have problems collaborating with other branches of the military. Different branches typically have their own operational doctrines holding five different view perspectives: dependency, objectives, tactical actions, space, and time (Hill, 2012). Dependency concerns the level of independence from external services a military organization can operate. For example, a military aircraft operates more independently than an infantry battalion does. Regarding objectives, although the strategic objectives of the branches are the same, the way to achieve their goals varies. Tactical operations concern the way to achieve the objectives. For example, while the Army tends to plan based on coordinated actions, the Air Force uses more direct actions. The perspectives of space and time are greatly related. Land, water, and air are tangible spaces and relatively more intuitive to understand. The "space" dimension is considered more concrete. On the other hand, time is a much more abstract concept (Peuquet, 2002). People usually perceive temporal relations between events and time, and not time itself (Le Poidevin, 2015). Thus, time is also defined as a subjective experience (Rao et al., 2001).

Time perception is part of an organization's culture (Blount & Janicik, 2001), and organizational periods vary widely (Blount et al., 2005). For example, while the Navy can have plenty of time to supply their vessels due to their relatively slow speed, the Air Force usually requires fast timing in order to supply their planes. For the Army, timing is mid-term (Blount et al., 2005); they have more time than the Air Force and less than the Navy (Worthen, 2008). Therefore, while tasks that could take up to a month to be completed by the Navy, might take the Army 1 to 3 days and the Air Force 1 to 2 hours.

Differences in varied cultures and perspectives can lead branches to produce uncoordinated actions that might generate unplanned effects (Grant & van den Heuvel, 2010). Many problems make it difficult for the armed forces to share information. They have a hierarchical mentality in which trained military personnel needs permission to act (Piccolo & Pagnozzi, 2013). The military also over-classifies information (Mishra et al., 2011). When in doubt, there is a tendency to increase confidentiality or repeat it unnecessarily; peers have the appropriate clearance to act.

Another problem with information sharing is the fear of information security threats. These threats vary from the leakage of information up to a cyber-attack (Liu et al., 2011a; Budney et al., 2008). For example, some emergency responses might not have the proper, private communication networks, depending instead upon commercial ones. This use increases the possibility of a cyber-attack (Nojeim, 2012) and makes their partners vulnerable. Therefore, many efforts towards improving security to counter the threat of cyber warfare have been made by the armed forces, such as improving firewalls, encryption, and infrastructure networks. However, technology evolves quickly and requires constant updating. Even when a department is able to assure, with some level of confidence, that their procedures, hardware, and software is secure, they are unsure about the other branches' security, reinforcing their fear of exchanging information.

Information is a powerful asset for decision making, and the technologies that support it are of the utmost importance to most organizations (Bertino, 2009). The threats are real, and the lack of confidence in the technology set-up to provide security keeps the military alert to those threats. On the other hand, those threats can be used as an excuse to avoid sharing and trying to safeguard privileged information in order to avoid losing "power" or exposing oneself to internal problems (Liu et al., 2011b). In some situations, even the total amount of information passed on from the government to each branch can be different, and some organizations could try to keep the optimum local resources to themselves.

After all those barriers are overcome, the military branches still have difficulties sharing. Even being willing to share the differences in organizational culture takes its toll, as seen in Hill's (2012) work. Different forces typically have their own operational doctrines and hold different perspectives regarding space, time, objects, tactical actions, and dependency. It is stated that armed forces branches have different needs or ways to operate. For example, the Army depends more upon logistics during operations than the other forces. The Air Force operates more independently. The differences are all around the branches and reflect their way of exchanging information (Hill, 2012).

Military branches, at the personal and organizational level, often have some willingness to collaborate due to understanding the advantages of sharing (Hajjar, 2014) and government incentives (Layfield et al., 2009). However, many factors still work against that sharing or the exchange of information. In this sense, we must highlight two basic requirements that are necessary to have access to that general information. First, the security clearance, which is granted by a competent authority to access classified information. Second is the “need to know.” It could be defined as a “personal” condition, inherent for the effective exercise of the function, job, or activity, and essential for a person in possession of security clearance to have access to data or sensitive information (Budney et al., 2008). These requirements also take place when it is needed to exchange information.

Rhythm influences searching and information sharing (Gorman & Ash, 2000). For Reddy and Dourish (2002), in hospitals, collaboration and information exchange are driven by the rhythm of the intensive care units. A broad working rhythm is identified and defined by the multiple temporal patterns existing in the work of intensive care units. Reddy and Spence (Reddy & Spence, 2008) reinforce the idea that, based on organizational rhythms, information is found and delivered on time. They stated that “when team members understood the rhythms of the unit, they also knew when the information was needed” (Reddy & Jansen, 2008, p. 257). In addition, Jackson et al. (Jackson et al., 2011) explored organizational rhythms to explain part of the collaboration in scientific work.

3.1.2 Time Perception

Space and time are closely related. Equivalent space and time are considered a principle of temporal science. For some, it is challenging to separate time from space.

Earth, water, and air are tangible spaces and relatively more intuitive to understand. The "space" dimension is considered to be more concrete. While Bergson defends the "spatialization of time," in which chronology becomes geometry, others defend the "temporization of space" (Peuquet, 1994), in which geometry became chronology (Oyelakin, 2014).

On the other hand, time is a much more abstract concept (Peuquet, 2002). People usually perceive temporal relations between events and time, and not time itself (Le Poidevin, 2015). However, time is also defined as a subjective experience (Rao et al., 2001) and is cognitively dependent. In this sense, time is not considered by itself but is dependent upon the mind's perception and the cognitive organization.

The different organizational rhythms and synchronicity of actions sometimes are related to temporal patterns. Time perception and the temporal dynamics of the time are also essential parts for a better understanding of the situation in those operations. Jaques (1990) studied time in organizations using the concepts of *kairos* and *chronos*. While the first considers "the time of episodes with beginning, middle and end or human and life time of intentions and objectives," the latter considers "chronological time; succession time, measurable by clocks or chronometers" (Hassard, 2016, p.33).

Gale used the concept of series A and series B (Gale, 1967). Time series A and B refer to different types of events and experiences, and our perceptual responses to these events and experiences, rather than different types of time. Time and distance are dynamic aspects of these scenarios or situations, being important to evaluate the possibilities of executing military actions.

The word “time” is used in the sense of “time necessary to defeat the enemy force” or to accomplish a specific task. They are usually used for planning actions; some tactical and punctual factors are considered, such as helicopter fuel autonomy, time to raise a field hospital or transfer the wounded. The rhythm peculiarities among the forces, especially at the operational level, quite often are not taken into account.

As previously stated, the exchange of information between organizations with the same culture will be more fluent than if they have different cultural backgrounds (Leidner & Kayworth, 2006). Therefore, the more we can reduce the differences, or make them compatible, the more information flows by reducing the communication barriers.

3.1.3 Military Rhythm

For the military, the doctrine dictates the rhythm. A cadence takes part in the way that they work and takes part in their daily tasks. Although each branch can have more than one doctrine for different purposes, overall, it also could be said that each branch can have a “tone” that is more likely to be played (Høiback, 2013).

Rhythm is also related to military organizations. For example, there are some expectations for operational rhythms for squadrons and platoons acting in military operations. There is also the concept of battle rhythm. This concept is related to the organizational military, defined as “a cycle of command and staff activities intended to synchronize current and future operations” (Joint Publication 3-33, 2018, p. IV-17).

Traditionally, the military uses the command and control mindset to deal with emergency response and tends to follow the battle rhythm. Especially for ERO, battle rhythm usually takes place by having time frames and deadlines to be achieved in terms of information needed (Huder, 2013).

In terms of information, battle rhythm involves four distinctive steps: receiving information from multiple sources, integrating information, making the integrated information actionable, and achieving a decision point (Torruella Jr, 2007). These steps are used at the strategic, operational, and tactical levels. Many times, the command and control way is strongly based on the tactical level, with much detailed information being exchanged. However, at any level, it is essential to achieve some synchronized moments in time where information is exchanged between organizations working in an operation. (Duffy et al., 2004).

Many times story-telling is used to explain, teach, and even analyze command and control. Although it could be possible to conduct this research exploring the rhythms using the Double Freytag model (Rao, 2011) based on storytelling, it was not chosen because that model favors command and control rather than collaboration. An approach was chosen that focus on welcoming different rhythms instead of enforcing them.

3.1.4 Situation Awareness

Situation Awareness (SA) is used in command and control and is an important concept in military operations (Dapoigny & Barlatier, 2013; Chmielewski, 2009). Endsley and Garland (2000) explains "…SA is knowing what is going on around you" (p. 2). A more formal definition is "the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future (Endsley, 1988, p. 97). In other words, SA is the consciousness about what is happening in the surroundings combined with an understanding of the information in that moment and feedforward.

SA is processed cognitively at three levels: The first level presents a perception of the elements of the current situation. In the second level, the perceived elements are understood by the activation of the memory mechanisms and direct or indirect association with schemes and plans closest to the perceived situation. At the third level, there is the manifestation of the feedforward mechanisms of the future states of the situation (Endsley, 1988).

Specifically in joint operations, SA is defined as the perception of the operational environment, in which all the military branches act. It is a recognition of the importance of each perception assigned to a mission element (Endsley, 2016). Therefore, the more accurate people's perception of the reality of the operating environment, the better the situational awareness is (Bar-Noy et al., 2011). This concept can be seen as an essential predecessor to decision making (Endsley, 2016).

Concerning to achieve the desired level of SA, a significant amount of information about the environment is necessary. The resources in various dimensions of performance must be made available in order to properly differentiate friends from foes. As a result, the proper provision of information to the right people in a timely fashion will result in the most accurate command and control decisions.

3.1.5 Sharing Information, Information Exchange, and Interoperability

Military branches willing to share information have had problems with different time perspectives and different modus operandi rhythms. For example, "fast" for the Air

Force seemed to have a different temporal meaning than “fast” to the Navy. Even without quantifying, it seems to me to be faster for the former than for the latter. It was possible to invest in a thesaurus that lists words with similar meanings within the specific domain of knowledge for ERO’s, for the systems. Then later, invest in more semantic layers over them. Despite the cost of those implementations, which were later rejected because their complexity and high price, they still maintain the rhythm difference problem. For example, once in a debriefing after an exercise, one Air Force pilot complained about the operator’s response time. According to the pilot, he lost the “target” due to that delay. Although the tactical forces deal with these problems as lessons learned for future personnel training, at that moment, we thought about creating a model for exchanging information to improve or avoid situations like those between information systems, and to make different time needs more “compatible.” That model could explore some temporal *a priori* and rhythmic *a posteriori* differences between the armed forces, but at that time, other issues got priority.

The military has Centers of Operations that often act as a fusion data center, using data warehouses, for example, to get and combine data from other organizations. Those models can also just execute a filter on what is being sent or received. Any structure where privileged information is exchanged is recognized as necessary in disaster response environments (Cinque et al., 2015).

There are also the mediation models that add a filter to the exchange process (Garcia et al., 2010). The mediation model approach in this dissertation is related to the Information Technology area. These models are developed to make possible components from heterogeneous environments work together. Mediation models apply to wildly different contexts as synchronize data among networks, sensors, and clouds. Many times mediation models are used for systems integration and interoperability.

Although the broad idea of interoperability is very desirable, in which we can increase the extension of organizations that can work and operate together to achieve a common goal, leading to more cooperation and synergy (Ghosh, 2009), in the implementations, we can observe many problems. For example, it is harder to achieve situational awareness with many participants in an operation.

3.1.6 ERO and Technical Solutions

Currently, much of the information sharing is done using technology, communication, and information systems (Alberts, 2002). When an organization faces an information exchange problem, an approach based on a technical solution is not uncommon. Unfortunately, quite often, information systems are not able to receive the needed information. In joint environments, it is vital to not only exchange information, but also to understand its context and act. The timely availability of data can positively influence the decision making process.

Many studies deal with response emergency as discrete events system simulations (Norena et al., 2011; Noori, 2016). In these systems, it is necessary that actions occur and that those actions generate events. One example can be seen in NeoCities, known as the human-in-the-loop event emergency response simulation (McNeese et al., 2005), that uses a formula for event growth magnitude to predict and simulate a human in the loop, event emergency response simulation. The event growth formula gives the core for the simulation, stimulating the user to resolve events or incidents through the correct and timely application of resources (McNeese et al., 2005). In addition, there is the software

Sahana Eden, an open source initiative for software, developed for all cycles of disaster management (*Sahana EDEN*, 2016). Recently, paid applications also are available such as DisasterLAN that is mobile friendly (*Future Shield | DisasterLAN*, n.d.)

Other solutions focus on database integration or technical exchange languages. From personal sharing to information systems sharing, sharing seems to be broader (i.e. conversations and knowledge sharing), while Information exchange tends to be more related to the technological approach. For example, we have models for data and for information interoperability, such as National Information Exchange Model – NIEM (DOJ, n.d.), Joint Consultation, Command & Control Information Exchange Data Model - JC3IEDM (Dogac et al., 2012, p.3), Humanitarian Data Exchange – HDX, and the Humanitarian Exchange Language (HXL) that are already in use (Keßler & Hendrix, 2015). We also have the Emergency Data Exchange Language Resource Messaging (EDXL-RM) (*OASIS*, 2014) that is set of standards for XML emergency response messages. We also have a data model for emergency response (Dilo & Zlatanova, 2011) and the Athena mobile application (Bahk et al., 2017) that can be utilized to improve crisis communications between citizens and law enforcement (Day et al., 2016).

Many solutions focus on database integration or exchange. However, for planning carrying out emergency response operations (ERO), it would be helpful to have only one information system (IS). That is very difficult to achieve due to the complexity of building and integrating a single system that would permit all the branches to plan and execute all operations. Therefore, each branch often has its own system and sends information to the operation command (Mishra et al., 2011), creating exchange problems as they do not "speak" the same language; Fonseca & Martin, 2005).

Specifically, within military organizations, since the organizational culture of each branch is different, they not only use data differently but also come to different conclusions when they receive the information. They make their decisions using the information received, but many times, the information quality is poor and not acquired on time.

Much has been said about data quality (Seppänen, 2015) and correctness in those operations. The data can be correct but be considered unnecessary for some organizations at the moment it arrives, but become important later, and it is hard to know the difference (Schein, 1985). However, the information overload effect can provide too much data and making it hard to find the needed data in a timely manner.

3.2 Conceptual Models

Conceptual models use concepts to address subjects or problems in specific application domains (Thalheim, 2010). Models use theory and constructs to build a representation of reality. In this work, the problem is the difference of rhythms in exchange information and the domain is ERO. Many models were developed in order to cover one or more phases of disaster management: prevention, mitigation, response, and recovery (Asghar, Alahakoon, & Churilov, 2006).

Due to the problems described further in Chapter 4, this work focused on conceptual models or frameworks that address the response phase of disaster management. In Table 3-1 it is partially applied the mode classifications according to Asghar, Alahakoon, and Churilov (2006) of logical and integrated classification.

Table 3-1. Conceptual Models/Frameworks on Emergency Response.

Model/Framework Classification	Model title	Reference	Explanations
Logical Models	Circular Model	Kelly (1998)	Intend to reduce the complexity of disasters and also handles the non-linear nature of disaster events.
	The four phases model of disaster management	Cyganik (2003)	This model uses mitigation, preparation, response and recovery phases of emergency management. It emphasizes the response phase.
	The five-stage model	Tuscaloosa (2003)	This model also inserts mitigation at the four phases of disaster management: prevention, preparedness, response, recovery and mitigation.
Integrated Models	Integrated Emergency Response Framework	Jain and McLean(2006)	Integrates many emergency response tools with different data sources and knowledge bases.
	Integrated system oriented model	Meshkati and Tabibzadeh (2016)	The model uses collaboration and interoperability of key entities and players. It covers the emergency response phase.
Coordination models	Framework for multi-agency coordination in emergency	Curnin et al. (2015)	Framework for facilitating multi-agency coordination in emergency management. It is theoretical and focused on Laison officers as human agents for information exchange.
	Theoretical coordination of the Armed Forces collaborative efforts with other organizations	Passos (2013)	It is a theoretical framework for the coordination of the Armed Forces collaborative efforts with other organizations. It focused in natural disaster emergency response operation.
	A four phase teamwork model	Owen et al. (2013)	Use a conceptual framework about teams working in multi-agency coordination. It uses a teamwork model that includes four phases: situation assessment; plan formulation, plan execution and team learning.
	Coordination Emergency Response Framework	Hussein, Alotaibi, and Ibrahim (2018)	The model combines the fields of coordination between multiple agencies and agent-based simulation for an emergency response. It has a technical perspective.
Temporal Models	A Model for Temporal Coordination of Disaster Response Activities	Franke, Charoy, and Ulmer (2010)	Identify the activities performed by the different stakeholders in an emergency and the temporal dependencies between these activities
	Response Delay Model	Yunus (2019)	The model deals with the delay moments in urban fire response. It is identified two delay moments: the pre-notification and the Intra-reflex sequence delay. These delays are synchronized to improve the efficiency of a response system. However, does not deal with many organizations.
	Temporal modelling of information foraging	Osatuyi and Mendonça (2013)	Deals with temporal analysis in which groups search and use information

Upon the classification exhibited in Table 3-1, models/frameworks related to emergency response subject, the dissertation's domain, were presented and analyzed. The classification is also expanded with coordination and temporal models due to the need for investigation in these subjects.

The logical models provide explanations of all the stages and basic actions that are made in each stage. However, the chosen models emphasize emergency response. The circular model (Kelly, 1999) reduces the complexity of disasters using classification for disaster stages by relating inputs and decision impacts. The four-phased model defines the phases of disaster management as mitigation, preparation, response, and recovery. Although it emphasizes emergency response, it is focused on the response of hospitals (Cyganik, 2003).

The Tuscaloosa model (Tuscaloosa, 2014) evolved by inserting prevention in the phases and having a mitigation plan. Integration models add planning and monitoring phases. Moreover, actions and events are linked to information systems modules. The integrated model (Jain & McLean, 2006) integrates individual tools that have different data sources in data cube dimensions to achieve interoperability and increase information about disaster events. Meshkati and Tabibzadeh (2016) also present a model that explains the need for interoperability. The model was made from studies of Persian Gulf needs and focuses on emergency response.

In Table 3-1 the works presented in coordination classification are models and frameworks chosen because they focus on multi-agency coordination. This choice is due to the difficultly of coordinating between different organizations. They are usually more theoretical approaches (Curnin et al., 2015; Owen et al., 2013; Passos, 2013). Curnin et al. (2015) presented a framework for facilitating multi-agency coordination in emergency management. It is theoretical and focuses on liaison officers as human agents for information exchange. Owen (2013) also presents a conceptual model for coordination in emergency management. It is composed of four phases: situation assessment, plan formulation, plan execution, and team learning. The focus is on teams working in multiple organizations. Passos (2013), based on qualitative research, developed a theoretical framework for coordinating the Armed Forces collaborative efforts with other organizations. It focuses on natural disaster emergency response operations and divides the critical areas into uncertainties, temporality, organizations, and social interactions.

On the other hand, Hussein, Alotaibi, and Ibrahim (2018) match coordination areas and agent-based simulation. It has a technical perspective, and the result is to find out the best-fit coordination mechanism depend on the emergency type. All these works incorporate human perspectives and culture into their models.

The temporal models presented in Table 3-1 are the models in emergency response that deal with time related issues. Franke, Charoy, and Ulmer (2010) identify the activities in ERO by different actors and the temporal dependencies, showing the temporal logic between two activities to be done. The response delay model (Yunus, 2019), on the other hand, deals with delays in these activities, synchronizing the moments that postpone actions and measuring the overall efficiency of urban fire response. Osatuyi and Mendonça (2013) follow a different approach, using the temporal analysis to model the distribution of efforts between seeking information and handling it. In fact, this last work emphasized the need for more studies on information flow in emergency response environments.

By studying these models, it might be highly tempting to conclude that using models and frameworks in ERO cannot be overemphasized. Several models have been developed over the last years to address many aspects of emergency response. However, to the best of our knowledge, none of these models addresses the different rhythms portraits of different organizations in these operations. Harmonizing these rhythms is essential to improve information exchange and, consequently, situation awareness. In addition, knowing the operational rhythm increase the chances of dispersing information even within an overwhelmed environment. Moreover, most of the works that talk about coordination problems in ERO do not present implementable solutions. Thus, there is a need to create a model to help with the differences in organizational rhythms.

3.3 Decision Making Models

The decision-making process can be defined as the application of different decision models (Steiner, 1977) and can benefit from Situation Awareness (SA). In organizational theory discipline, the decision making process is fundamentally the majority of the tasks that occur in organizations (Simon, 1978). Decision theory is prescriptive and normative, where models and rules are defined (March & Simon, 1958). However, many studies state that the decision making process also involves a conscious or unconscious selection of certain actions among those actions which are physically possible for the agent, and for those people over whom they have influence and authority (Ansoff, 1991).

Using models for decision making allows for understanding the organizational structures and the complex relationships inherent to the development process in ERO. The decision-making process involves applying different decision-making models, and each one is relevant, or better applied, to a specific situation (Allison & Zelikow, 1999). Decision models present a "big picture" of the variables and their amplitude, in order to help identify possible relations between elements, understand the complexity of relationships, and establish and improve parameters. Nevertheless, it can limit identified variables since some assumptions are being made before one even starts to gather information.

The Simon's models (1978) of decision were also looked in order to make decision model rational is highly structured and is based on rules and well defined procedures leading toward a positive result. The rational model is more adaptable to closed systems in bureaucratic organizations in which rules, regulations, and procedures are formal and routine. In this sense, the term "rational" is better related to the operations.

The procedural model explains the phases and cycles that subsidize the activities of decision-making, which are complex and dynamic activities. This model was initially developed by Mintzberg, Raisinghani, and Theoret (1976), and it focuses on the phases, activities, and dynamics of decision-making behavior. This model is similar to the rational model but is more flexible because it uses activities and dynamics, such as interruptions and advanced deadlines, as a path for decision-makers to make adjustments when needed.

In the Garbage-can model or Anarchic model (Cohen et al., 1972), the goals and the procedures are ambiguous. In this model, organizations have no consistency with problematic events and decisions resulting from the meeting of independent streams of problems, solutions, participants, and situations of choice play out. Individuals throw out many types of problems and solutions as they are generated. The decision occurs when problems and solutions coincide. Michael Lipson (2007), in his study regarding UN Peacekeepers, reinforces unclear priorities, limited understanding of technology, and a high turnover of positions in the organization. Thus, it is an encouraging environment in which to use that model for the understanding of how decisions are made.

Another decision model is the incremental model proposed by Charles Lindblom (Lindblom, 1979), which views the decision-making process under successive limited comparisons. This model is descriptive and recognizes that the choice of objectives is not independent of values and, in this sense, its implementation will be subject to all kinds of interference, since each actor involved will have their own perception of the problem and its solution. In this model, reducing options facilitates comparisons and simplifies the decision. A mix of rational models and incremental models can be seen in the mixed-scanning model proposed by Etzioni (1967).

Allison proposed the bargaining model (Allison & Zelikow, 1999) based on the fact that government and public administrations have various power centers within their infrastructure. Thus, many interests, both personal and collective, conflict with each other in pursuit of traditionally scarce resources. In this context, there is, inevitably, selective distribution of information, and political use of laws and regulations for the benefit of one's own goals. Here, decisions come as a result of power games, negotiation, and consensus. Maximization is seen from a political perspective rather than an economic one.

The above models seem to be more strategic and descriptive, explaining how decisions can be made. On the other hand, traditional military decision-making models such as the OODA model (Observation, Orientation, Decision, Action) (Shahbazian et al., 2001) and variations of OODA (Grant & Kooter, 2005) are more prescriptive in terms of methods and procedures, to achieve better results. Therefore, regarding the proposed research subjects, these models broaden one's horizons in terms of high-level decisions. In other words, while military models address many concerns directly involving military operations at the operational and tactical levels, they might not be able to be utilized at a strategic level.

Even though military models lead to the discovery of weaknesses in cycles (Kronenberg, 1988), many times, they lack an emphasis on information sharing. This lack could lead to less information available for making decisions. Many works talk about the importance of information sharing between intra and inter-organizations (Cinque et al., 2015; Alcará et al., 2009).

There is a common understanding of how sharing of information can increase planning operations details, situation awareness, and decision making. However, even when understanding the mission and the benefits of joint operations, the different perspectives (Noori, 2016) of the U.S Air-Force and U.S Army, for example, cause them to share less information than is desirable (Hill, 2012).

Decision-making is also a process that is highly influenced by the cognitive styles of decision markers. Therefore, even if we can improve the information exchange and SA, there is a greater probability — but no guarantee — that better, more timely decisions will be made.

3.4 Information Units

Since the introduction of the word "information" by Shannon (Shannon, 1949), the world is dealing on a daily basis with this intuitive but often unclear concept. The Merrier-Webster dictionary defines information as (1) "the communication or reception of knowledge or intelligence." Even if the definition of information is not precise enough, it is assumed that information flows among the components of a system, technological or not. Therefore, there are different meanings to the word “information” in which the semantic concepts are related and interchangeable (Carnap & Bar-Hillel, 1952).

In the information systems area, for example, “data” is considered pure facts, such as signals, characters, and patterns. Data are the raw elements that are captured, recorded, stored, and classified. Information is organizing that data to convey meaning; it is the interpretation of data. Knowledge, in turn, has a more complex sense than information and can be considered as information processed by users to express experiences, accumulated learning, or skills (Aamodt & Nygård, 1995). However, what one person sees as information might be considered knowledge by another.

In the same manner, as information is not a clear cut definition, we have information units. This expression, and similar ones, are used in many distinct ways. However, we define an information unit as the smallest piece of something or a unit that can be used as a measure. For example, in the egoist gene book (Dawkins, 2006), genes are a unit of information since they can multiply themselves and propagate from one being to another. In the information management area, many times “informational unit” is an organization (Poças, 2015, p.339) or a library itself.

In this work, an information unit refers to any type of information that is transferred from one organization to another. One could argue that receiving the information unit in a system is an event itself, even if it is received at a different time than the physical event. In addition, many times, the information unit itself is not enough to cause a change in the system in terms of SA. When did the events happen? Moreover, what was known at that time? (Al-Taha, 1992). Therefore, we make a distinction between information unit and event unit.

An information unit is the smallest piece of information that actually carries workable information. Initially, the idea was to use the conceptual units of information theory and computation fields. For example, “bits” as an information unit, “bytes” in operating systems, and even “word” could be considered units. In these cyber times, we also consider a URL, a web page, or even a tweet, a unit. In Granular Computing, the granules are the information units (Cornelis et al., 2008). According to Leite (2012), “An information granule is defined as a clump of entities that may originate at the numeric, singular, or granular level and are arranged together due to their similarity, proximity, indistinguishably, or coherency” (p. 12). The smallest unit of information is different from the essential unit of information. Therefore, in order to conceptualize the essential unit of information, the literature makes many references to an information granule, and many of the references are related to the computer granulation field. The goal of a granule is to catch the very essence of the overall data in a concise and explainable manner (Pedrycz, 2013).

In a palpable area, such as construction in civil engineering, there are clear distinctions between the smallest portion (the grains in raw materials) and in compaction granules (in briquettes and pellets). Even though there could be some confusion between what a pellet is and what a compaction granule is, when the product is delivered, both sender and receiver understand what is being delivered. On the other hand, due to the intrinsic abstract characteristic of the information, it is not rare that we could argue that a sender is sure to deliver a pellet and that the receiver is sure to receive a briquette. In other words, it is hard to define the level of granularity of information units in the organizations and especially in information exchange. We can have documents, videos, messages, events, and many more exchanges around information systems or command and control environments.

In music, the “grains” are very brief, sounds lasting less than a few milliseconds. If they last more than 100 ms, the sound is audible, and one can get a sense of its pitch. Adding to pitch, volume, and tone, we have musical notes (Sethares, 2007). However, like the pellets in civil engineering, many times, a “standard” note in music theory is a quarter note, mainly in popular music. It is a common notion that it is easier to make abstractions and understand the whole. In the coming chapters we will explain our abstraction of a musical note, that is, the information unit (IU) and its relation to music and rhythm.

We define information unit (IU) as the most basic element to be exchanged between organizations in an operation. It can be an event, an order, an information question, or an answer. In other words, it is anything that could be transmitted or informed to another organization.

Donahue and Chung (2013) use a timeline exchange language for exchanging temporal information, an ontology for use in Jet Propulsion Lab projects. We argue that instead of exchanging temporal information, we should exchange information while respecting the necessary rhythms of each organization.

4 Mini-Case Study of Serrana Operation

Serrana Region is a mountainous area in Rio de Janeiro state with 2,300 Km2, population 713,000 (Busch & Amorim, 2011), and altitude varying from 400 to 2,400 meters. Due to cooler weather, this region is also where some spend their summer vacation in January. In 2011, there had been heavy rains at the beginning of the month. Landslides started the night of January 11^{th}, in which the Firefight brigade executed rescues. In 24 hours, the rain was almost the amount expected for one month. The soil was already very wet, and the unusual downpours, concentrated in groups of 15 minutes, helped to erode the soil, creating “veins” in the mountains. Thus, on January 12^{th}, between 3 a.m. and 4 a.m., many people were sleeping when major landslides struck the entire region. Buildings and houses collapsed under the force of the water laden with earth and rubble. The full rivers contribute to the flood; some neighborhoods were swept, and many families die buried in their homes.

The disaster officially caused 947 deaths, with 300 disappearances, more than 50,000 homeless, and affecting almost 1,000,000 people (Dourado et al., 2012). The red area in Figure 4-1 represents where disaster hit, which was in rural and urban areas of the cities of Nova Friburgo, Teresópolis, Petrópolis, Areal, Bom Jardim, Sumidouro, and São José do Vale do Rio Preto in Rio de Janeiro state, Brazil.

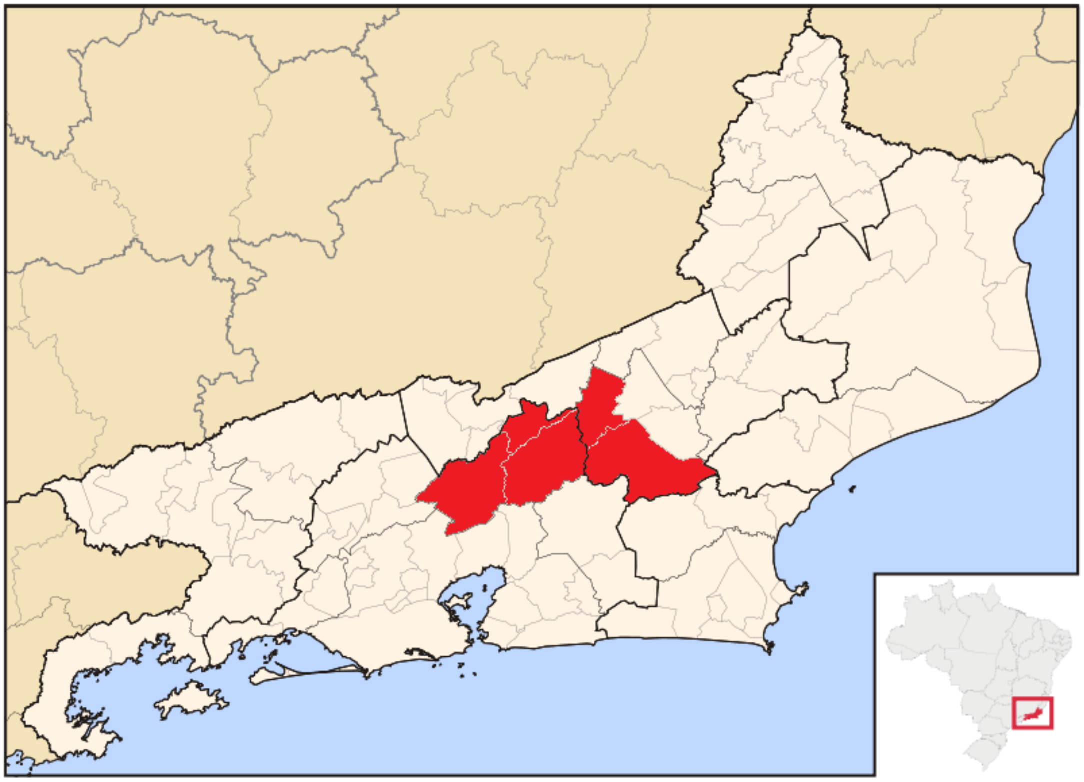


Figure 4-1. Region area of flood and landslides in 2011 (Soares,2011) in Rio de Janeiro.

The region was without electricity, drinking water, and communications of any kind. Public buildings and hospitals were damaged. The rescue teams operated without using cell phones, satellites, or radios. Many towns were isolated.

The Armed Forces cooperated with the National Secretariat of Civil Defense (NCSD) in this ERO, according to the laws and regulations at that time (Passos, 2013). Due to many problems in widespread locations, an Integrated Security Operations Center (ISOC) was established in each one of the three larger cities: Nova Friburgo, Petrópolis, and Teresópolis. The ISOC's were coordinated by local Civil Defense because they knew to cities. Also taking part in the ISOC's were the Armed Forces, State Civil Defense, Civil Police, the Security Secretariat of each City Hall, Military Firefighters Corps of Rio de

Janeiro National Security Force, the Military Police of the State of Rio de Janeiro, the Red Cross, State Government, Civil Police, and local leaders.

In this crisis management, the Military Police of the State of São Paulo, Municipal Guard of each city, the Department of Mineral Resources, Unique Health System (UHS), and the National Water Agency also took part. The private sector was also present, including Petrobrás, the telecom companies CLARO and VIVO, who opened their mobile phone signal, Electric Company ENERGISA, the Municipal Urban Cleaning Company of the City of Rio de Janeiro, Inspection of Estrada Rota 116, the Brazilian Environment Company, the State Public Works Company, and others. Veterans associations, NGO's, volunteers, and others also played a role.

To support the Civil Defense, and in collaboration with its National Center for Risk and Disaster Management (NCRD) through the National Center for Risk and Disaster Management (NCRDM), the Armed Forces had a center that coordinate that support, the Federal Military Forces Operations Center (FMFOC). The Center, coordinated by the Army, was responsible for coordinate the military but not the firefighters, Military Brigade, nor the Military Police, as those are state forces. The Air Force, the Navy, and the Marines, which in Brazil are part of the Navy, had Liaison Officers in this Operation Center that coordinated based on command and control fashion. Moreover, each branch had an organization that was responsible for that branch. In the Army, it was the 1st Army Division Command (1st ADC), in the Navy, the 1st Naval District (1st ND), and in the Air Force, it was the III Air Command (III AirComm).

In the FMFOC, support requests were received, such as the donation report from the city of Rio de Janeiro to the municipalities affected by the disaster. These requests mainly came from the State Civil Defense Center and the COSI's. Besides, all requests for help were registered, and the missions were monitored. However, it was observed that sometimes, the military organizations were contacted directly with requests by other government organizations, and the FMFOC was not always informed about an action or its details.

The Navy acted more in Nova Friburgo, the most affected city, where the Field Hospital of Nova Friburgo (FHosp-NovaFriburgo) was installed for surgeries and other medical treatments. The Operative Marines Group (OptMGr) was moved there under the operational control of FMFOC (Lopes, 2016). Three helicopters from naval aviation were dedicated to transporting people and supplies, and a Social Assistance Service was installed in the Naval Sanatorium of Nova Friburgo (NSNF).

The Army coordinate the operation in collaboration with State Civil Defense. The field operations in Nova Friburgo were the responsibility of the artillery division of the 1st Army Division (AD/1). In Teresópolis, it was the command of the Group of School Units/9th Motorized Infantry Brigade (CGSU/9th Mot Inf Brig), and in Petrópolis (everywhere except the Itaipava neighborhood), it was the command of the 4th Motorized Infantry Brigade (4th Mtz Inf Mtz Comm). Platoons of the Engineering School Battalion (BEsE) were sent to these cities. The Army controlled its Granja Comary, where elements of the Army Aviation Command were based on six helicopters. The terrain missions were clearing roads and removing debris, mapping the area blocked after the disaster with drones and showing the best access to areas that were still isolated, and facilitating the rescue work of the victims and bridge launching works. They also had a transportation center for managing the dispatching of trucks and other vehicles.

The Air Force acted more in Itaipava, Petrópolis where there was the Field Hospital of Itaipava (FHosp-Itaipava). The Air Force performed logistical tasks, distributed supplies, evacuated the wounded, and provided medical treatment. They had even aircraft dedicated to flying in supplies from other states, as well as additional flights. Its Department of Airspace Control (DAC) controlled all the helicopters that come from different places, including 11 dedicated helicopters from armed forces and more than 19 others authorized to fly in the disaster area.

In brief, the Armed Forces assisted Civil Defense in this catastrophe with searches and rescues, the distribution of medicine, supplies, food, and water, and facility security. In addition, they helped to recover the mobility of the population affected by the floods. The whole ERO for the Armed Forces took 17 days; the tasks were divided into short term (up to 72 hours), medium term (from 72 hours to 10 days), and long term (more than ten days). The federal forces in this ERO had 1,307 military personnel distributed as follows: Army 861, Navy 215, and Air Force 231. The military achieved the objectives established by the MoD (Lopes, 2016), and they performed well.

4.1 Knowing Your Data

After the major flood and landslide in Brazil at Rio de Janeiro State, in 2011, mentioned earlier, the Chief of the ERO asked for an event timeline in which the military branches should show the interaction between them. The idea was to have a better understanding of the actions for dealing with the disaster in order to better understand and evaluate their performance as a whole.

At that time, it was not possible to create a timeline with the information available. Many descriptive reports regarding different actions and understandings were found. Temporal granularity was also a problem with some reports detailing each action hour by hour, while others were giving overly concise descriptions of the tasks they carried out.

To understand data over that specific time frame, a new analysis was started. Initially, the idea was to look at the data from the perspective of different perceptions of time and rhythms. The existing data was spread and scattered in reports, different databases, spreadsheets, and was unstructured, including data from newspapers and media interviews. Therefore, the information units varied for each branch. In addition, as already expected, the information followed the flow from outside to inside the Center of Response Operation (Militello et al., 2007).

The analyses started with the information of day Jan 12^{th,} "Concentration of all personnel and material from the Marines Operative Group (GptOpFuzNav) in the Naval Complex Caxias-Meriti. Activation of GptOpFuzNav-NovaFriburgo at 21:01h" (Costa, 2011, p.2) and followed the first 70 hours of the operation. Figure 4-2 shows the number of tasks that were executed by each force. From this chart, it is clear that the Brazilian Navy executed the most actions in the beginning, acting as first responders. The Army was more active than other branches after 30 hours, while the Air Force was engaged last. However, it was found that many actions were not detailed enough, or it was not reported at all.

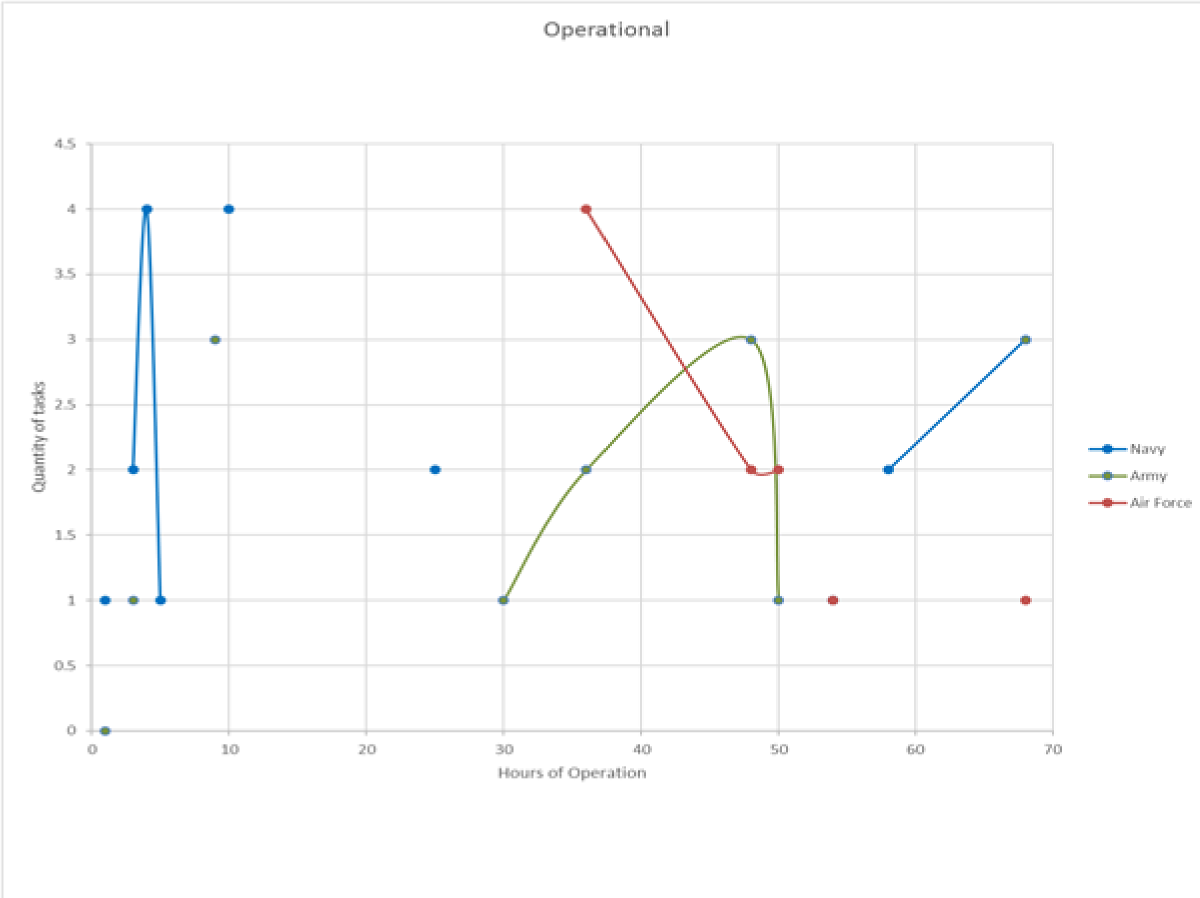


Figure 4-2. Tasks by military organizations in ERO.

Although the findings from Figure 4-2 were consistent with the execution times carried out by each branch, in the end, to carry out in-depth research about the branches timing required data that did not exist or was not accessible. By getting a sense of the available data, the problems with information exchange in operations started to appear.

Analyzing IU's, we found empirical evidence that there is a relationship between the relative "speed" of the branch and the quantity of information exchanged. There is a tendency to think that the faster branch should be the one exchanging more information. Although this may be true for tactical information, in terms of exchanging strategic and operational information, this assumption has not been confirmed. The preliminary data suggested quite the opposite. The "slower" force tends to exchange more information.

4.2 Understanding the Problems

This study looked at armed forces report and annexes (FMFOC, 2011); online news (Vianna, 2011; G1, 2011; Teixeira, 2012; Quaino, 2012); works (Brazilian Ministry of National Integration, 2011; Bush and Amorim, 2011; Rosa, Bandeira & Leiras, 2014) and dissertations (Dourado et al., 2012; Passos, 2013; Oliveira, 2015; Júnior 2016) about the disaster. They all mention coordination problems. However, some details about the problems were found in websites and other academic works that complemented the occurrences reported in the official documents.

Despite many coordination problems, the military achieved operation the MoD directive objectives, and the resource usage were detailed in the reports (FMOC, 2011). However, it was noted that many times resources were double spent on problem solving. The branches operated well in their missions, but they sometimes were not effective when having to work with other organizations.

The coordination problems were one major issue and were the object of many studies (Passos, 2013; Rosa, Bandeira & Bandeira, 2015), as well as the logistics (Costa, 2013; Oliveira, 2015; Lopes, 2016; Fontainha, Melo & Leiras, 2016) from a humanitarian perspective. Although the word rhythm was not specifically mentioned in the reports, differences in information exchange were noted. Their rhythms were different. For example, the ISOC's were often times too slow to pass information to the FMFOC that had to make decisions in the field. The information flow was not explicit; the granularity of the information was very different, so there were moments they exchanged information. The lack of synchronization that leads to duplicated efforts were mentioned in the reports and detailed in online news. Leaders missing from decision making in essential times were also reported. In addition, problems such as duplication, overlap, and missing timely information were identified.

Among the coordination problems, it was found the lack of synchronization between the organizations. There was a coordination meeting at 08:00 a.m. in each COSI, but it was not enough for the information exchanged. It was tried to synchronize efforts and tasks. However, even if, the official discourse encouraged the information exchange between organizations, that exchange did not happen as necessary. Besides, it lacked synchronization.

4.2.1 Lack of synchronization

It was found that synchronization problems sometimes occurred in that ERO. Although inside a branch, synchronization happened when acting with other branches, not always. Much of this is due to not knowing the different cultures and rhythms, as already mentioned. For example, the Navy social communication released a note for media, and almost at the same time, the Army released another note. Some divulged details of ERO at Nova Friburgo were different, which made the press call attention to the lack of synchronization.

Another problem that might influence the lack of synchronization is the different standard times to accomplish similar tasks. Sometimes these standards are well defined inside a branch. When operating together, differences in tasks such as medical transportation (Rettke, Robbins & Lunday, 2016) might be implicated in executing tasks differently from previously planned or expected. Although some evidence of different execution times took place in this ERO, one of the most found problems from the lack of synchronization was the Duplicated Efforts and the Missing Leader.

4.2.1.1 Duplicated Efforts

The duplicated efforts not only spent more resources than necessary but also jeopardized other tasks. When these duplicated efforts happen, the chances are that other areas and people in need are left without help. It was found that sometimes happened the duplication of efforts among the organizations acting at that ERO, as reported here:

"Only by helicopter is it possible to reach very remote places in the mountains... when the residents heard a helicopter approaching, they came to ask for help, some type of food or to rescue someone who needed help. A boy joined the team to show the way for an isolated community. Upon arriving at the site, it was found that the families had already been rescued…"(G1, 2011).

"... In just 15 minutes, the military was already flying over an isolated property to try to land and serve the group of about ten people who showed up to collect the supplies. ... the rescuer goes down by the tow truck and is provisionally left in place to finish the service, and the aircraft goes on to the second part of the mission ... in the rural area of Teresópolis, the aircraft manages to land. It is the time to bring back military police officers assigned to take care of the supplies previously distributed and see that they are divided equally among the people of that region. Nevertheless, they had already been removed" (Porto, 2011).

"The Air Force helicopter was sent to remove some corpses. They did not find them." (Oliveira, 2015, p.74). The civil defense had already removed the corpses.

4.2.1.2 Missing Leader

Another problem that might be related to lack of synchronization and also happened in this ERO was that leaders were not available for decision making eventually. It is a problem already mentioned in the literature (Denn III, 2018), as seen in the following description: "A team of 45 soldiers, for example, waited for a day for the decision of the mayor of Teresópolis to set up a bridge." (Busch & Amorim, 2011, p.19).

4.2.2 Information Overlap

It is known that information overlap, in the sense of the same information shared between team members, increases the performance of the team and the Situation Awareness (SA) (Mesmer-Magnus & Dechurch, 2009). It was observed in simulated ERO exercises that when information is frequent and similar, operators tend not to pay attention to incoming messages. For example, tactical information, such as tracking the position of infantry, might make operators not pay attention to other information arriving. In other words, the information overlap might cause "unintentional blindness" (Coon & Mitterer, 2012) and Attentional blink (Beanland & Pammer, 2012). The problem is that different information from that source might not be seen. Even if the information is there, it is not taken into account. Thus, new information might "get lost" (Wu & Keysar, 2007) in routine information (Rodgers, 1992). The times in which information is presented affects the human processing of information (Kearney et al., 2019). There is evidence that changes in rhythm might help operators acquire visual information more efficiently (Thomas, 2015).

4.2.3 Different Durations

The idea in the model is to give a limited number of characters that briefly describe the information. Detailed reports might have been sent on later, but without getting rhythms in place. What was found is that while received some short information, others come as detailed reports, and it was hard to compare them or to update information at a screen in FMOC.

In ERO, usually, there is a set time for organizations to send their situation report (sitrep). Many times, these sitreps times are very different from the organization's battle rhythms. When it is the case, the organization does not send anything or just sends any information to comply with the rule or protocol for that operation. This situation was also observed in the Joint Civil Defense Exercise (ECADEC), in which, among many scenarios, some of Serrana Operations were simulated (ECADEC, 2017).

4.2.4 Different Temporalities

It was found that many times the information exchanged refers to a time that already passed, for example, yesterday or last week. It might occur very late regarding the action or very early. In other words, it is extemporaneous. Many times and it is hard to act on this information at that moment. For example, when the action happened in one week ago and is being reported on that day. In addition, when using simulated systems, there is a problem to accept information from a scenario with time ahead of the current time. For example, it was found the following information about a helicopter accident, "The misfortune of the accident that occurred during operations with the aircraft EB 1032 was quickly absorbed by the crews and served as a stimulus for an even more intense work to help people in need." (Junior, 2011, p.4). However, there was not found the exact time of the accident, and this was reported late in operation.

4.2.5 Different Granularities

While much information was exchanged about the details and the time, some consolidate actions, and it was found that the information was exchanged was from different granularities, make it very difficult to get a temporal sense of this ERO. For example, while the Navy, throughout 1st ND, reported "Actions of 14th January…The UH-14 aircraft took off at 11:40 am, carrying 14 firefighters, 1 journalist and 1 military photographer to the Friburguense stadium." (FMFOC, 2011) while the Air Force throughout the III Air Command reported "It was sent 52 food and overnight support tents to Force Petrópolis." (FMFOC, 2011).

From the difference in granularities, it was also found that the consolidation of information in exchange often discards details that would be useful for the EOC and other branches. For example, detailed information from the Air Force about one or two tents that would be placed near Petrópolis could have helped the Army, specifically the engineers of the BEsE platoon, to have hot food when they started to work at rural areas.

4.3 Mapping the Temporal Problems in Information Exchange

Temporal aspects are considered an important part of situational awareness (Endsley, 2016; Endsley & Garland, 2000) and its implementation. Currently, it is accepted that human beings can only deal with a limited number of objects at one time. Many times, receivers of the information cannot discern the level of information's importance at the time of its arrival and may consider that information noise.

The uneven rhythms of organizations might worsen that problem due to the constant alertness that receiving information requires. If important information is disregarded or ignored, because of information overload or excessive time waiting for new information to arrive, the receiver might end up missing or disregarding relevant information. If using an information exchange model that accommodates different rhythms, players that are given little or no training could deal with the overload of unrequested information over their systems.

Figure 4-3, we represent some exchanges that are made between the Navy and Army. The idea of information being exchanged between Navy and Army are presented in one timeline for each branch. In (a), we have information that is exchanged; in (b), we have a lack of information. Here, we can see that information is not synchronized, which at this point, may or may not be disruptive for understanding the situation. It is shown for the Navy, at times 2 and 4, some units of information are larger than others. It is inferred that we have the same kind of information with a distinct duration. At time 3, we also see a big box. That box signals a different kind of information, which semantically may refer to times in the past or in the future other than the current one. In the Army, we also see at times 1, 2, and 4 two information units overlapping.

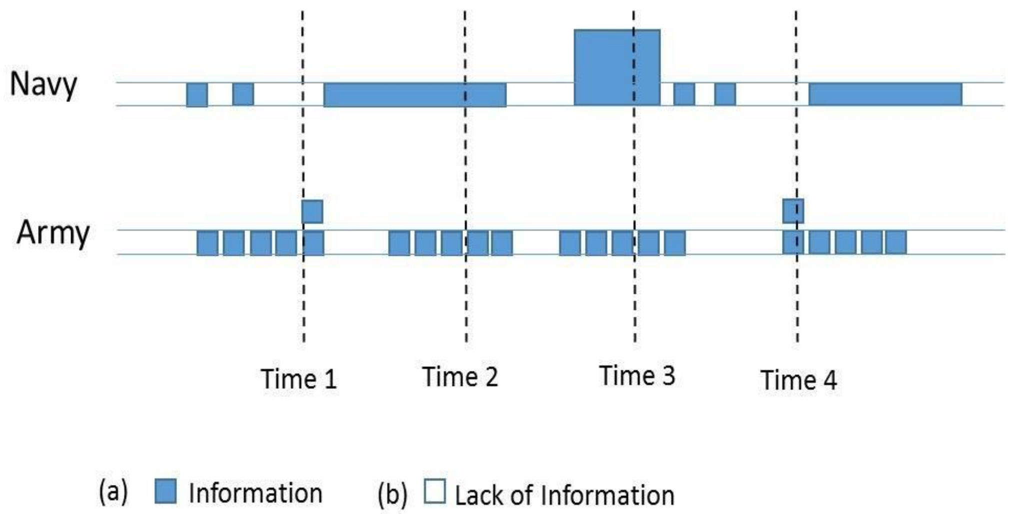


Figure 4-3. An abstraction of information exchange in military organizations over time.

From the problems discovered in the exchange expressed in

Figure 4-3, we identify five types of temporal problems that occur between military organizations with different rhythms. We categorized them as follows:

Type I - refers to a lack of synchronization. In this case, the organizations can use the same time clock, but they are not operating at the same pace. In this work, it also encompasses duplicated efforts and missing leader.

Type II - refers to different durations of an information unit.

Type III - refers to temporal overlapping that occurs when two or more information units are frequent and similar.

Type IV - refers to the same temporal granularity, but one which is temporarily too far ahead or behind a window to make decisions. This difference can cause information to get lost in time, and it is yet another problem of information overload.

Type V - refers to different temporal granularities.

The categorized types of problems were pointed out in Figure 4-4. The red circles show the moments in which the information exchange happened.

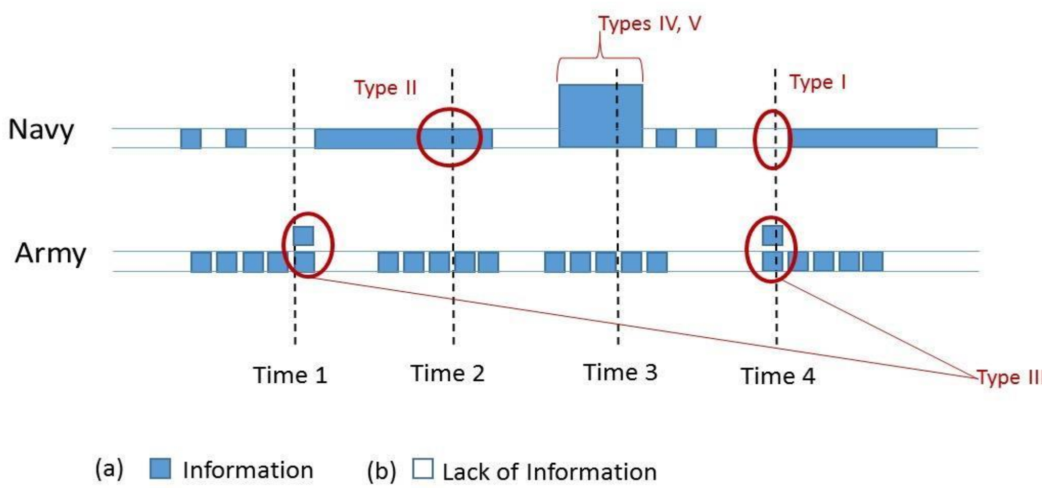


Figure 4-4. Example of information exchange problems, types I, II, III, IV and V.

In this work, we specifically addressed types I, II, and III. However, it is essential to understand that the temporal problems in types IV and V do, in fact, exist. They are, for example, embedded in the problems to be solved by the NATO Modeling and Simulation Group (Khimeche, 2014). Although we will not address them in this thesis, we believe that understanding and solving types I, II, and III will support a future solution for the problems presented by types IV and V.

We defined *key moments* (discussed in detail in the next chapter) in information exchange for a specific branch and for the exchange itself. These key moments arise from the rhythm that organizations already have and are hard to make explicit. Therefore, we make some inferences in pace and tempo.

Table 4-1. Types of Problems Addressed in our model.

Categories of Problems	Description
Type I	Lack of synchronization
Type II	Different durations of an Information Unit
Type III	Temporal overlapping

The problems addressed by our model are presented in Table 4-1. For dealing with type I, we defined durations for those units and also defined how to fit them in the established rhythm for an organization. We defined operations for how to deal with unsynchronized information from the perspective of the branch that is not the source of information. By doing so, we also addressed type II.

Each organization has a doctrine for communication and information exchange and deals with types I, II, and III. We considered that rhythms in information exchange might be similar to the rhythms in music. Which concepts related to rhythms might be used for creating an information exchange model that accommodates the different rhythms that occur in activities during an ERO? In the next chapter, the concept of rhythm is explained, and other concepts that inspired the model are explored in depth.

While Franke, Charoy, and Ulmer (2010), created a model based on temporal restraints for coordinating activities in disaster response, our model takes a different approach by accounting for rhythm for each organizational entity. We know that behind every exchange of information, there is an event, action, history, or other reason motivating the exchange. To the best of our knowledge, no research has yet related rhythm to information exchange nor applied it to emergency response operations.

4.4 Further Analyses

After that disaster, many lessons that were learned were already implemented. The role of Civil Defense as the leaders is more consolidated, and systems for Situation Awareness and MoD logistic and mobilization that help with national facilities control and follow-ups, are also used. However, in many operations, similar coordination problems can still occur.

The analysis of the Serrana Operation is consistent with the literature, in which organizations prefer to work intra-organization instead of synchronously with other organizations (Khorram-Manesh et al., 2016). Although it may be challenging to deal with more than one center responding to an emergency, it is consistent with literature that states it is very hard to achieve centralized coordination for large scale disasters (Groenendaal, Helsloot & Scholtens, 2013; Kapucu & Hu, 2016).

Temporally synchronizing information to be exchanged helps to synchronize actions. The reports presented well organized tasks that were accomplished. The details of the tasks mostly were not registered. However, many times their execution could be improved. One way of doing that is by organizing information exchange in a way that adapts to each organizations' rhythm. Using a pace for each one and identifying the best moments for exchanging information leaves leaders more attentive to make a decision around those moments.

Since the objectives were achieved and the operation had some success, communication problems and the lack of timing to achieve them are not detailed or emphasized enough. However, inside the coordination problems, there was information and different cultures. Cultural differences are widely cited as one of the main factors for coordination problems in ERO's. Differences in rhythms are part of these problems (Hill, 2012).

All in all, the information available was insufficient and presented the problems mentioned in previous sections. In addition, rather than analyzing past operations, where it is already knowledgeable about the different timing between the branches, there is also a need for a model that can harmonize the information to be exchanged. In order to create the model, the temporal problems in information exchange were examined. Models oriented to the exchange of data and semantics were developed to improve the exchange of information in ERO, but as far as we know, using musical inspiration to assist in the compatibility of different rhythms is not developed yet. Besides, a common rhythm must be found.

5 We’ve got the Rhythm

Organizations participating in Emergency Response Operations (ERO) frequently have different views on how to respond to unpredictable events. Their response often is based on their rhythms that many times are not evident. In order to look specifically at the hidden rhythms that run in operations, a model was constructed based on organizational rhythms. This model presents a new way to organize the rhythm of how information is exchanged, improving the synergy among all organizations participating in an operation.

The focus on rhythm is inspired by music theory. For many years, music has been used as a metaphor for collaboration (Becker, 2016). There is a common understanding that music is one of the universal forms of communication and that it often transcends and crosses many cultural barriers (Arom, 1989). Music allows for improvisation. Even without much experience in playing together, experienced musicians improvise with the rhythm of others, adapting to the (sometimes unanticipated) notes played by other musicians. Our approach considers then that the universal language of music may be used as a paradigm for information exchange.

This chapter describes the proposed model of information exchange between organizations in an emergency response joint operation. We consider that these organizations have different rhythms in how they conduct their daily activities. This model was developed and adapted from the theoretical ideas presented earlier in this dissertation. The ideas were borrowed from music theory, specifically polyrhythms, and rhythm timelines.

5.1 Organizing Information in the Model

Just as many experienced musicians do not think about rhythm while playing (they keep rhythm naturally), organizations tend to follow their own inner rhythm while executing their tasks. To a certain extent, a parallel exists between playing different instruments all together and communicating within a joint operation.

Two or more rhythms being played together can create another rhythm, as they match or interlock in a way that might create a “groove,” or a pattern that can be perceived in music. An emergency response operation could be compared to a complete musical piece. Each participant has its respective part in the operation, and those parts will interact with others in the operation in order to construct the complete piece. In order to apply these music principles to communication exchange in a joint operation, a method was developed to support and organize information exchange using rhythms.

The model attempts to reduce the mismatch that happens during information exchange between organizations working together in an operation. The exchange of information is a single point, but usually, it is not known a priory when it will happen. The attempts to synchronize these exchanges are not always successful due to differences in the rhythm of the organizations. By applying the model, information exchange moments will be defined dynamically. These moments will lead to a unique but variable pace of exchange of information.

Just as many instruments do not produce all notes, many information systems do not record some events or actions. In an ERO, it is necessary to achieve some level of synchronous situation awareness. However, it is usually difficult to have the events recorded in different systems on the same timeline, since the events themselves might have different granularities and different time durations, making synchronization in communication among different participants complicated to achieve.

Quite often, communication problems arise due to the difference in rhythms and lack of synchronization. An organization sends out information when it can instead of when the other side needs it. This timing may not be appropriate for those on the receiving end, as the different rhythms of the organizations may not be in harmony. To that end, our model is designed to harmonize different rhythms.

5.2 The Model

The goal of the model is to organize and impose rhythm onto non-rhythmic, random pieces of information coming from organizations with different rhythms. In order to organize information traffic, this work conceptualizes information exchange in terms of polyrhythms. Each organization in an operation performs in an individual rhythm. All the rhythms together form a polyrhythm. The polyrhythm was the inspiration for creating the key moments.

The proposed model will define a rhythm for the traffic of information. The model refers to the temporal perception that each organization has of its own information flow. We used the Son Clave to create a template. In addition, the pace might be decreased or increased to suit the rhythm of each branch.

It is worth noting that the model prioritizes the operational level in which different command centers interoperate. Our model intends to be a “ritmo franco,” or a rhythm for exchange information analogous to the “lingua franca” used in the interoperability for Information Systems Research (Tolk, 2004; Benson, 2012, p.28). Simply put, the model is made from a set of simple conversions that fit the information of one organization into the rhythm pattern of the other organization. For this purpose, we defined a *mediator bus* in which all information is exchanged at specific points that we called *key moments*.

5.2.1 Concepts and Definitions

We define the key terms of our model as follows:

- **Rhythm –** In the context of this project, rhythm indicates a temporal sequence of slots to be filled with information.
- **Slot –** Slot refers to the basic information container. Each slot may contain up to one Information Unit (IU).
- **Information Unit (IU) -** refers to a piece of information exchanged among organizations.
- **Onset –** In music, onsets are sounded pulses, or the start of a sounded note. In our model, the onset is the time in which we have to insert an IU.
- **Rest –** In music, a rest or silence indicates a unit of silence. In our model, there is a rest or silence that is measured at the same time period and can occupy slots of time. The rest means that there is no information in the slot. We define the silence as meaning the non-existence of the information.

Package – The package is the information set that has been accumulated by one organization between two key moments. In Figure 5-1 there is a numbered package with 3 IU's inside.

Figure 5-1. Package representation.

- **Key Moment (KM) –** The KM is the intersection of the onset of two or more masks. All information is exchanged in the key moments. In Figure 5-2, there is a representation in yellow of a slot with a Key Moment.

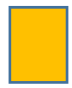


Figure 5-2. Key Moment Representation.

- **Rhythm Pattern (RP) –** Rhythm Pattern (RP) is a set of slots that contains rests and IU’s and displays a coherent pattern of information that is defined for the operation. In our model, we define a sequence with 16 slots, in which 5 of them will be completed with IU, similar to the use of Son Clave explained in Section 2.5.
- **Rhythm factor value –** It is a value that is given based on the ratio defined by observation of previous operations. Each organization receives an initial value.
- **Mask –** A mask is a result of multiplying a Son Cave rhythm pattern by a rhythm factor value.
- **Metronome –** In music, it is a clock that produces regular pulses at variable speeds. It is used here as an abstraction for an operational clock. It is implemented by the KM use in our model.
- **Temporal Window (TW) –**Temporal window refers to the period of time that is used as a basis for decision-making for each entity or organization. In this work, the TW is an interval composed of a group of slots used by each organization with the purpose of exchanging information.
- **Mediator –** It is the place in which all IUs are organized.
- **Mask –** Is the Rhythm Pattern for each organization, in which the IU will be inserted.

5.2.2 Assumptions

Our model relies on some assumptions we have made, based on music rhythm abstractions in conjunction with personal knowledge in military emergency response operations:

- **Directionality -** The information exchanged is unidirectional. The information goes from the organization's source rhythmless flow to the rhythmized flow. The contrary direction is not possible. In the same manner, the rhythmized flow goes to Mediator.
- **Reversibility -** The exchange is non-reversible.
- **Priority -** All IUs have the same priority. Although we are aware that priority can vary among some IUs, our model considers all IUs to have the same priority over the course of information exchange.
- **Temporality -** In a timeline among different information systems, the exchange information does not happen in the past. Therefore, the model is no addressing the problem type IV (same granularity and different temporality) addressed in 4.2.4.
- **Environment -** The conditions (such as network transmissions) are considered ideal, without noise or delay.
- **Exchange Completion -** All information generated will be sent at some moment. All information sent will be received.

5.2.1 Rules

The following rules are designed to convert the random flow of information into an organized flow that obeys the Son Clave:

- **Rhythmic rule 1**: An information exchange operation starts when more than one organization is engaged in an emergency response operation.
- **Rhythmic rule 2:** Each IU is allocated according to the Son Clave mask.
- **Rhythmic rule 3:** If there is already information in the slot, the IU will be added to the next free slot.
- **Rhythmic rule 4:** The Mediator stops looking for KMs when only one organization remains in the operation.
- **Rhythmic rule 5**: The rhythm flow of an organization stops when the whole operation is demobilized.

5.2.2 Elements

In this section, we used some rhythm representations for the model development. The representations are shown in Figure 5-3. In a) using the TUBS notation, b) using the necklace notation, and c) denoting the distance from one beat in an onset to another one. This formalization represents the Son Clave.

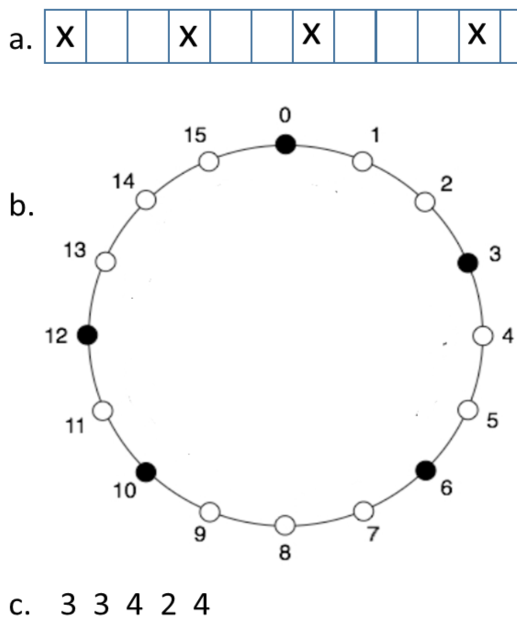


Figure 5-3. Different notations used for modeling.

5.2.3 Compounding Rhythm

When the participants' rhythms of a joint operation are put together, they form a new rhythm: the polyrhythm. The polyrhythm plays all the rhythms simultaneously. It must be observed that the organization does not usually know how its own rhythm compares with that of others in a joint operation. Thus, a command center should define the pace of each organization based on previous knowledge acquired by experience. That pace is translated in a transfer function that normalizes all rhythms in a Mediator.

In other words, an information exchange occurs under predetermined control conditions designated by the Mediator. In Figure 5-4, a relationship between rhythms is represented in the circle notation. For each time that Organization B completes one cycle, Organization A completes four cycles. The model uses a rhythm factor value α that represents the organization's pace. This value is used for multiplying time periods in the Son Clave. When there is one RP for Organization A ($\alpha_a = 1$), we are going to have 4 RP ($\alpha_b = 4$) for Organization B. In other words, for each IU in Organization B, is equivalent to a time period with 4 IU in the Organization A.

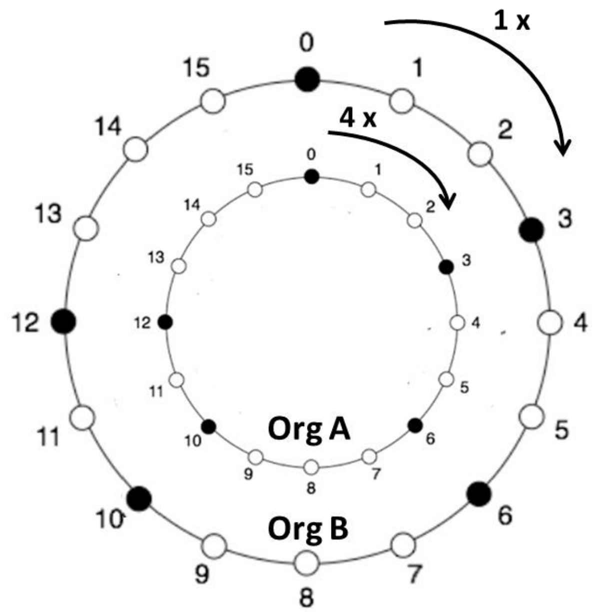


Figure 5-4. Relationship between rhythms.

When

$\alpha_a = 1$ for Organization A, then $RP_{orgA} = 3\ 3\ 4\ 2\ 4$; and when

$\alpha_b = 4$ for Organization B, then $RP_{orgB} = 12\ 12\ 16\ 8\ 16$.

These values varies for each organization, but the relation that they establish between organizations will be specifically used for the model construction as described in the next sections. In fact, the rhythm factor is also related to the concept of Temporal Window (TW). The $\alpha_{a\ =}$ n is a number that multiply the RP values and define the total number of slots for one TW of each organization. TW concept is important because it explains the reasoning for the model.

5.2.3.1 Slot Conceptual Representations

Each dotted rectangle (a) in Figure 5-5 is represented one slot, and each slot indicates a period of time that contains one IU. The timeline of the operation (b) is composed of slots. The timeline starts when the first organization joins the operation and ends when the last one leaves.

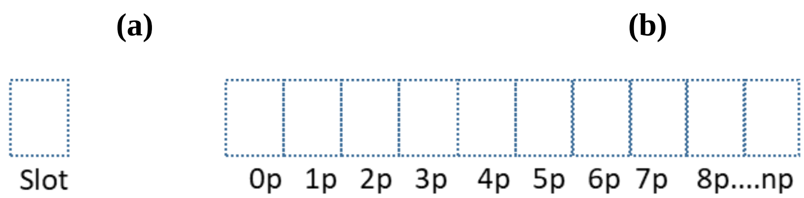


Figure 5-5. Slot representation.

The Slot 0p initiates a temporal sequence of slots that runs from 0p until the end of the operation. An organization may join the operation at any slot. For example, organization A may enter the operation at the slot 4p, and 4p will mark organization A's initial slot, even though 4p is not the initial slot of the entire sequence. Each organization has its working timeline embedded in the main operating timeline because there is only one Mediator for the entire operation.

5.2.3.2 Basic Slot States

From the slot concept, we built the other elements of the model. Individual Information Units (IU) are represented as an X inside the slot, as can be seen in Figure 5-6. The IU can occur in many formats, including text message, cryptograph message, standard message, latitude and longitude positions, voice, picture, radar screen, sonar files, and a variety of other media.

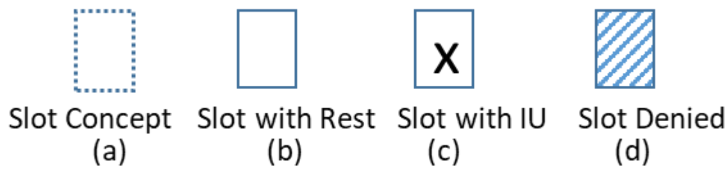


Figure 5-6. Basic slot states.

Thus, the basic status of slots for our model, presented in are: (a) the slot concept (as also seen in Figure 5-6); (b) the slot with rest or silence; (c) the slot with an IU; and (d) the slot denied. The slot is just a time slice that can have an IU or rest or may be denied. If an analogy with a database were to be done at this point, the slot concept would be the Null value, and the slot with rest would be related to blank space value.

Given these basic concepts, we now move to the rhythm pattern illustration. First, we use the 16 slots that represent different rhythms. The set of 16 slots will be repeated, creating the basic model for a rhythm pattern presented in Figure 5-7. This pattern is the smallest set representing the Son Clave.

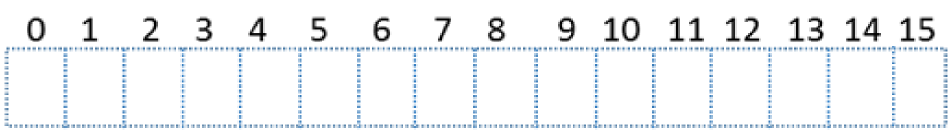


Figure 5-7. Sequence of 16 slots.

Although we use the slots with a dashed line in Figure 5-6 (a) and Figure 5-7 to explain concepts, from now on, we will only use the representations with a solid line as we did in Figure 5-6 (b), (c), and (d), to explain the model. The slots in the model always have a Rest or an IU, or alternatively, the slot is denied.

5.2.3.3 The Son Clave

Figure 5-8 shows the Son Clave rhythm sequence. That clave is a sequence of 16 slots. The slots with an "X" represent the onset of the musical rhythm. It is also an IU. In our model, the IU's can be inserted in these slots. The empty slots mean rests.

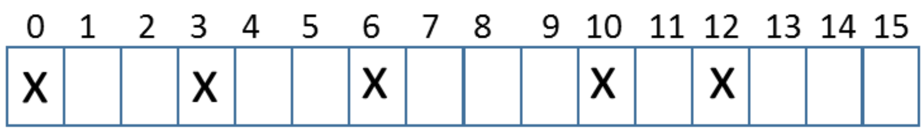


Figure 5-8. Son Clave Rhythm.

The initial operations of an organization are a rhythmless flow. A transformation step is necessary in order to create a rhythmized flow for that organization. Each organization will have a rhythmized line, as seen in Figure 5-9, that will receive all the information and will be arranged according to the organization's rhythm. Thus, each RP will receive five IUs or rests over 16 slots. Therefore, 11 slots are denied slots that act as mandatory rests to create a rhythm.

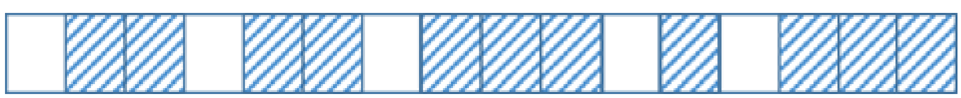


Figure 5-9. Definition of the Mask based on the Son Clave Rhythm Pattern.

As shown in Figure 5-10, the rhythmized flow is created based on the mask in which the empty slots can be filled with IUs, and, as shown in Figure 5-9, the previously empty slots are filled with the 5:16 RP.

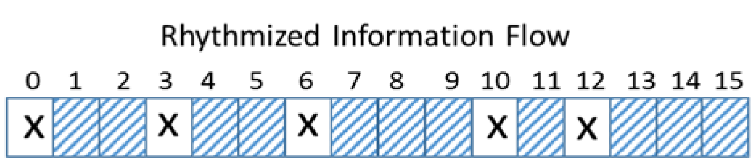
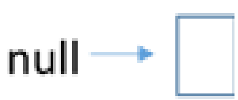
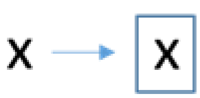
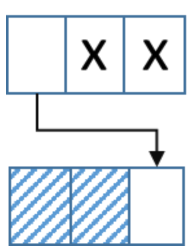


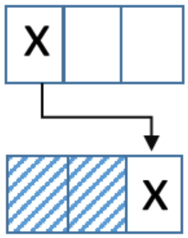
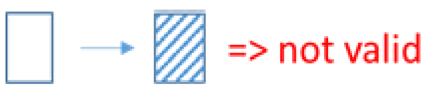
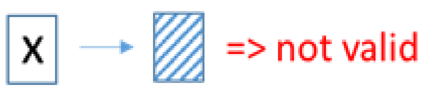
Figure 5-10. Rhythmized flow of an organization.

5.2.4 Basic Model Operations - Insertion and Comparison

The details of the model operations are presented in Table 5-1. Possible operations in the model. These basic model operations are atomic, and therefore they are the smallest operations allowed.

Table 5-1. Possible operations in the model.

Symbols	**Name of the Operation**	**Description**
	Insert Rest	This operation inserts a rest in the empty slot.
	Insert IU	This operation inserts an Information Unit "X" in an empty slot.
	Shift Rest	This operation moves a rest from one slot to another slot

	Shift IU	This operation moves one IU from one slot to another slot
	Compare the input and the rhythm pattern sequence	If there is a rest and the RP expects an IU, then this operation is considered invalid
	Compare the input and the rhythm pattern sequence.	If there is an IU available and the RP expects an IU, then the IU is written in the result

5.2.5 The Model at Work

We consider that each organization has its own rhythm for information exchange. Since the organizations do not consider the rhythms of other organizations' participants of ERO, the information flow seems rhythmless. Thus, this flow might be reorganized in order to make the rhythm compatible with other organizations.

To achieve that compatibility, we are going to follow three steps presented in Figure 5-11:

Step 1) Transform the rhythmless into a rhythmized flow

Step 2) Define the Key Moments

Step 3) Perform the package exchange among the organizations

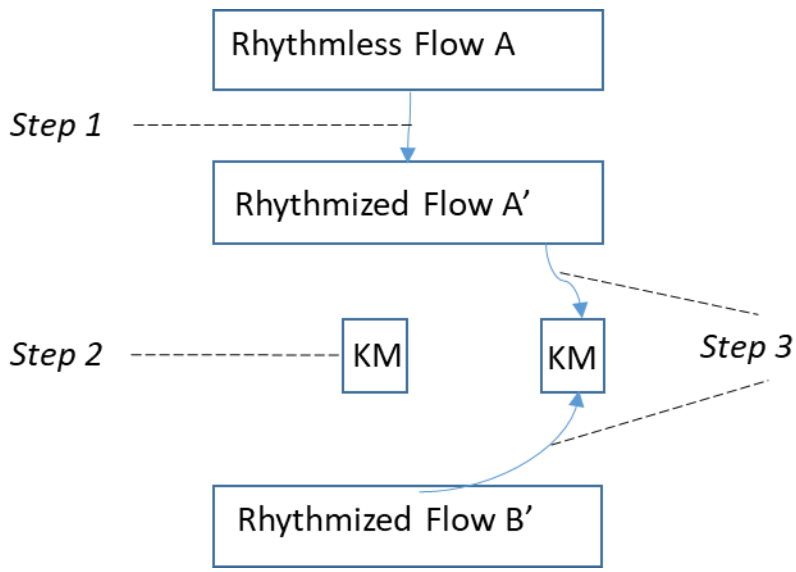


Figure 5-11. High-level model definition.

This model allows each organization entering in the operation to continue to send and receive information according to its own rhythm. The model respects the information exchange rhythm of each organization in the ERO functioning as a virtual, flexible, and variable metronome.

In order to explain the model, the steps in Figure 5-11 are detailed as follow:

Step 1) Transform the rhythmless to rhythmized flow

Figure 5-12 represents the initialization of the operation. Each slot is a representation of a period. These periods are defined for the entire operation and can represent any time length, for example, seconds, minutes, hours, days, making the model able to be used in different situations. For example, in the use of flight operations, it can be configured in seconds or even shorter periods to handle digital systems. An empty slot or the moment of silence means that, at that moment, there is no information to be sent.

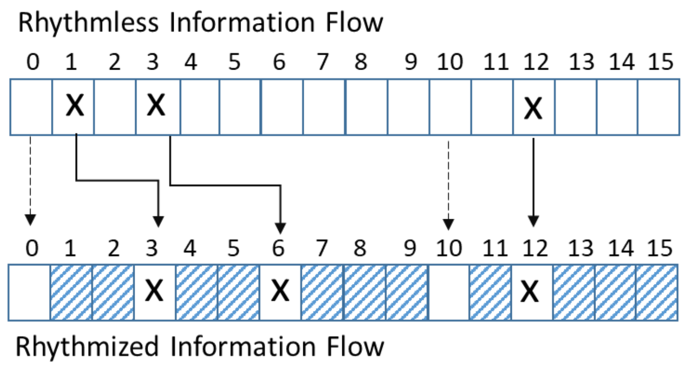


Figure 5-12. Rhythmizing information for one organization or branch.

In Figure 5-12, a hatched slot means that no information is to be inserted in that slot. Since there is no value in the slot to be sent to slot 0 and 10 in the Rhythimized Flow (Son Clave), the corresponding slots in the Son Clave continue as a rest in the rhythmized flow. In this case, we use a dotted arrow to indicate that there is no information to be exchanged. In the rhythmized information flow, an open slot can have an IU or a rest. In fact, the hatched slots create the spaces that make the distribution of IUs organized as a rhythm pattern based on the Son Clave. However, even if there is an empty slot, there is no obligation to fulfill with an IU.

To accommodate the needs of this research, the Son Clave abstraction used here departs from the regular use of the Son Clave. Even though the Son Clave has beats in specific periods of time, the absence of information in these positions maintains the rhythm of an organization. As can be seen in Figure 5-13, the Son Clave used as RP (Rhythm Pattern) is a useful abstraction for a model to rhythmize one organization

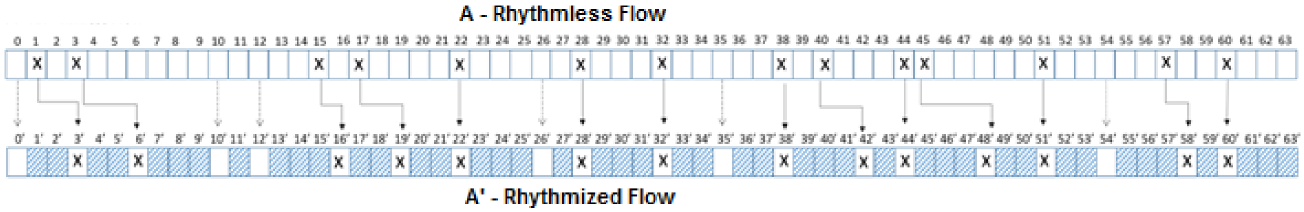


Figure 5-13. Rhythm for Organization A.

In Figure 5-13, the rhythmless flow for Organization A has been organized into the rhythmized flow A’. The slots 0, 10, 12, 26, 35 and 54 are null. The slots 0’, 10’, 12’, 26’, 35’ and 54’ are also null. The slots 1’, 2’, 4’, 5’, 7’, 8’, 9’, 11’, 13’, 14’ and 15’ are hatched to create the RP. In A’ the RP repeats 4 times, as seen in the slots 0’-15’, 16’-31’, 32’- 47’ and 48’- 63’.

An IU in bar A will be moved to the corresponding time slot or routed to the next possible slot in bar A'. Thus, in Figure 5-13, the IUs in slots 1 and 3 were moved to slots 3' and 6', respectively, in the rhythmized flow. It should be noted that the IU in slot 3 was not able to occupy slot 3' because it was already occupied by the IU coming from slot 1. Thus, the IU from slot 3 had to be allocated to slot 6'. The IU in slot 12 in bar A was sent to the corresponding slot 12' in bar A'.

In Figure 5-14 is presented a rhythm for Organization B. For clarity, this time, the symbol “Δ” is used as IU for Organization B. The rhythmless flow of Organization B in bar B, and their transfer to a rhythmized flow in bar B’ is shown. It corresponds to what was done for Organization A in Figure 5-13.

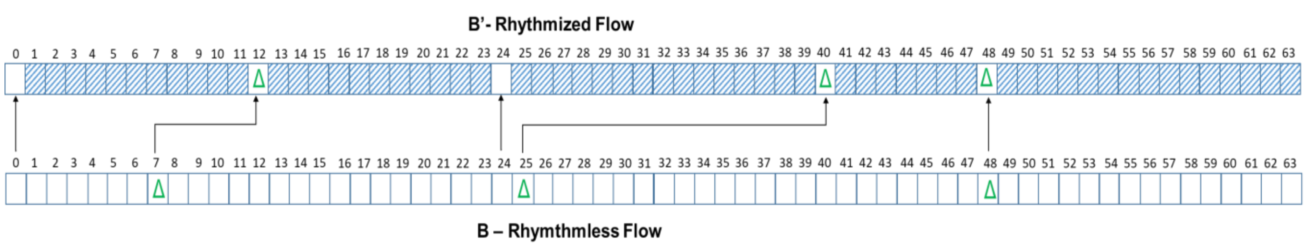


Figure 5-14. Rhythm for Organization B.

The rhythmless flow starts when the first organization joins the operation. The rhythmized flow starts as soon as a second organization joins the operation. The difference between them is that in the rhythmless flow it is the random information that flows in an organization while in the rhythmized flow it is the same previous flow but now organized using the Rhythm Pattern. The rhythmized flow ceases when only one organization is left in operation. The flow stops when the last organization leaves the operation.

Step 2) Defining the Key Moments

While the Son Clave was used to organize the flow from one organization communication with another organization in an operation, a polyrhythm must be used when rhythmizing the interaction between two or more organizations. The main idea is to find the key moments (KM) at which the organizations send information. In these moments, the organizations are available for exchanging information.

A KM is a moment when there is a coincidence of open slots in the rhythmized flow bars of all organizations. In other words, the KM's are given by the intersections of the mask created to rhythmize each organization as shown in Figure 5-15. Communication among organizations takes place in these moments. The first key moment is defined when a second organization joins the operation with its own rhythmized flow. The KM, slots colored in yellow, are the moments in which the information is exchanged.

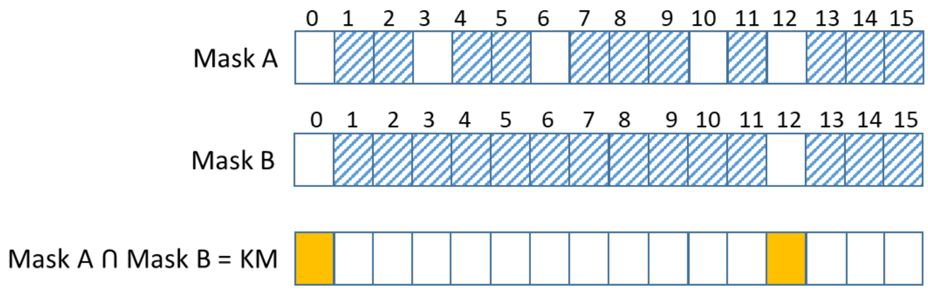


Figure 5-15. Defined Key Moments (KM).

Step 3) Exchanging packages among the organizations

In Figure 5-16 the Mediator M is presented. The packages are comprised of the IUs exchanged among all the participating organizations since the most recent KM. The IU's are represented by the symbol "X" for Organization A and **"∆"** is for Organization B.

A package is the set of IUs that is sent in a key moment KM from the Mediator to all the participants of the operation. They are just IUs concentrated, neither rhythmless nor rhythmized. Together, the IUs in bar M are in a package beginning at the start of bar M or the last KM. Thus, in the KM 00, we have the initialization that happens when an organization enters into operation, and it is also a KM for the exchange of the information. For example, "ready to start" message.

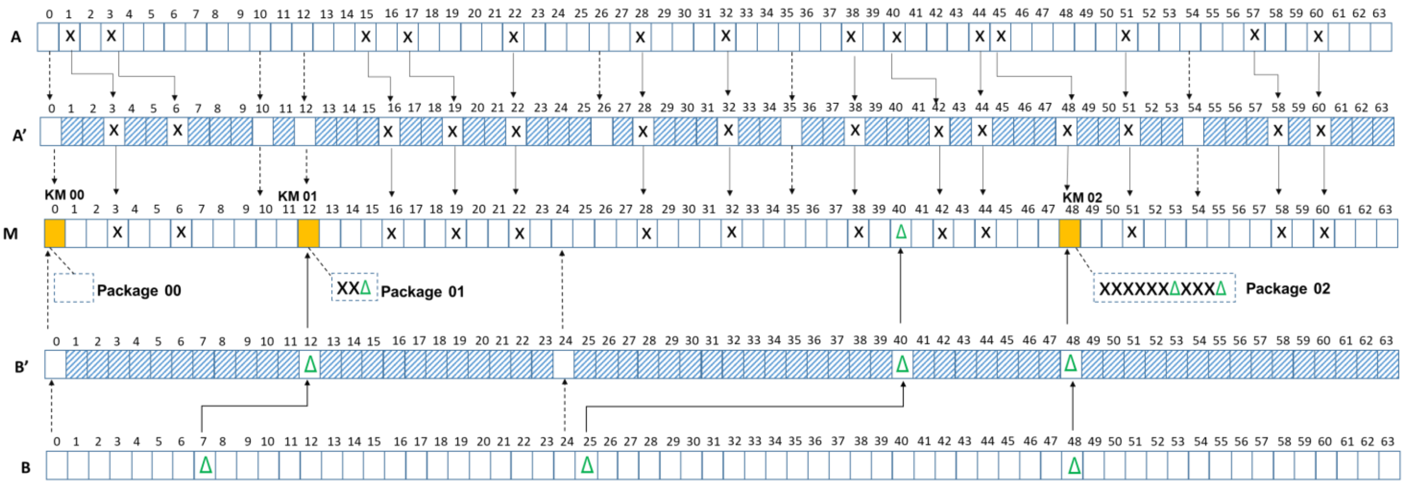


Figure 5-16. Mediator bus (M) in operation with two organizations (A and B).

Each KM is associated with a package. Packages are exchanged every KM. In Figure 5-16, it is also shown three KMs and their three associated packages. At each KM, the current package with IUs is locked, and another package is started immediately, to be used at the next key moment.

Each organization has one rhythmized flow and sends its IUs to M. There is only one timeline for an operation, and it is given by the bar M when the first organization joins the operation. The IU of that first organization joining the operation will be buffered until the first KM after its entrance.

When a second organization joins the same operation, it uses the timeline of the operation established by the first organization. For example, as shown in Figure 5-16, an organization can get into the operation at 63p, although that time corresponds to moment 0, to the organization that is getting in.

For each organization that joins or leaves an operation, the key moments of the whole operation will change. For each entrance or exit, the KMs have to be recalculated for the whole operation. In fact, most of the organizations are blind to other organizations' rhythms. In a nutshell, the M bus has the rhythm of the operation given by the KMs and consolidates all rhythms into a single line.

5.3 Temporal Window Reasoning

Figure 5-17, we present dotted lines that delimit Temporal Windows. These lines represent the concepts used when reasoning about the model. It can be observed that the TW duration for Organization B is longer than the TW of Organization A. As already explained in section 5.2.5, for each TW of organization B (TWB1), we will have four TWs for Organization A (TWA1, TWA2, TWA3, and TWA4). However, for operations timeline analyses, it is possible to dislocate a TW, backward or forward, enlarging it or reducing it a posteriori, just to verify and suggest different TWs durations as better candidates for each organization in future ERO's. It must be remembered that the value used is the rhythm factor that helps to create the information exchange relationship between organizations.

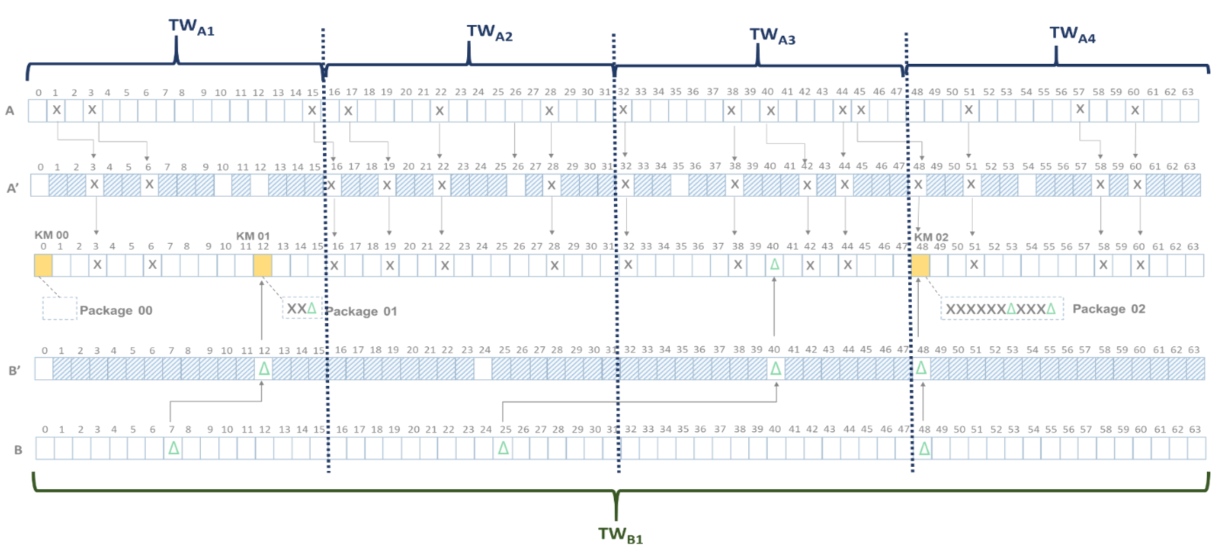


Figure 5-17. TW abstraction layer over the model at work.

Figure 5-17 presents how TW might be used as an abstraction to think about the model. We argue that TW also can be implemented as a visual tool for further adjustments in the model pace because an ERO can be analyzed under a TW view as well. However, we developed a verification approach that is specifically used for rhythm appropriateness in terms of pace and the relation between TWs.

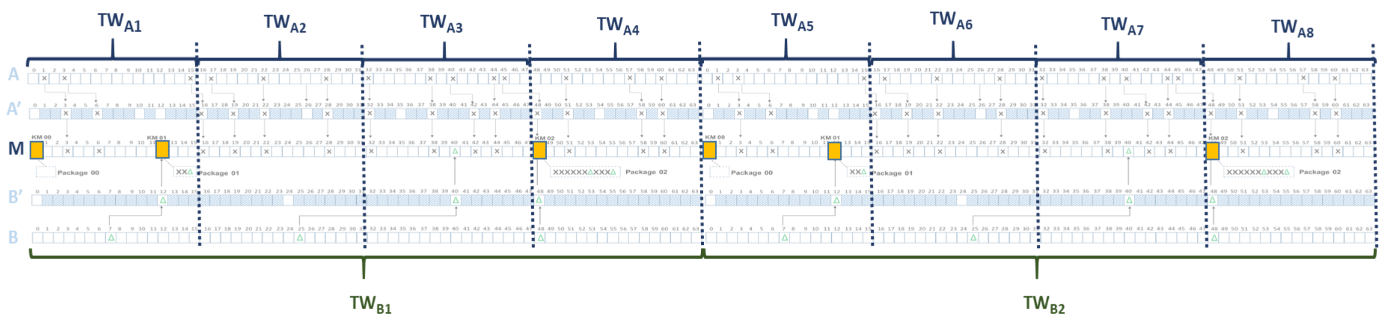


Figure 5-18. Key Moments highlighted in Mediator Bus.

Figure 5-18 shows an imaginary snapshot of the operation and a high-level view of the Mediator presented in Figure 5-17. There is no information exchanged in TW_{A2}, $TW_{A3,}$ $TW_{A6,}$ or TW_{A7}. Thus, KM's happen at each two TW's of organization A. In other words, in this example, the onsets of the KM keep the rhythm of the ERO in each two $TW_{A's}$.

Based on figure 5-18, abstraction is made for a zoon out of the model using another perspective or greater granularity. For example, if we consider TW's as slots, KM's can be the slots in which information is exchanged. If we apply the model repeating the timeline, but instead of slots, we use TWs, we can have several exchanges of information or several KM's in a TW.

For better use of the model, we can check the number of TWs in which there is no exchange of information. In music theory, there is a minimum and a maximum time between beats so that there is a rhythm. Making a parallel with music, we defined a useful interval of the distance between the beats. The pace between the KMs can vary up to ten times the distance between two KMs. We will use two TWA for the minimum distance to be maintained and 20 TWA for the maximum distance between TWs, without any KM happening. These heuristic values need to adjust the pace. This adjustment can be made at run time.

However, the information exchange pace given by the KM should be compatible with the pace of the organizations participating in the operation. If the ERO pace is too slow or too fast considering the rhythm given by the model, the rhythm might be hard to keep. Therefore, the pace assigned to the organizations will have to be monitored to suit the pace of the operation. The reasoning for the suitability will be presented in the next section.

5.4 Rhythm Suitability

Different temporal dynamics occur during an ERO. The beginning of the operation is when we have a busier environment and, consequently, more exchanges of information. Then the ERO tends to stabilize for much of the operation. After the stabilization period, information exchange tends to reduce until the end of the operation.

If in the stabilization period, there are peaks of information exchange, for example, due to a second accident during the operation, which may even be greater than the first disaster, one can increase the pace and reducing the rhythm factor. To do this, we have to change the rhythm factor and the mask that is explained in Section 5.2.3 and recalculate the Key Moments as each organization enters or leaves the operation.

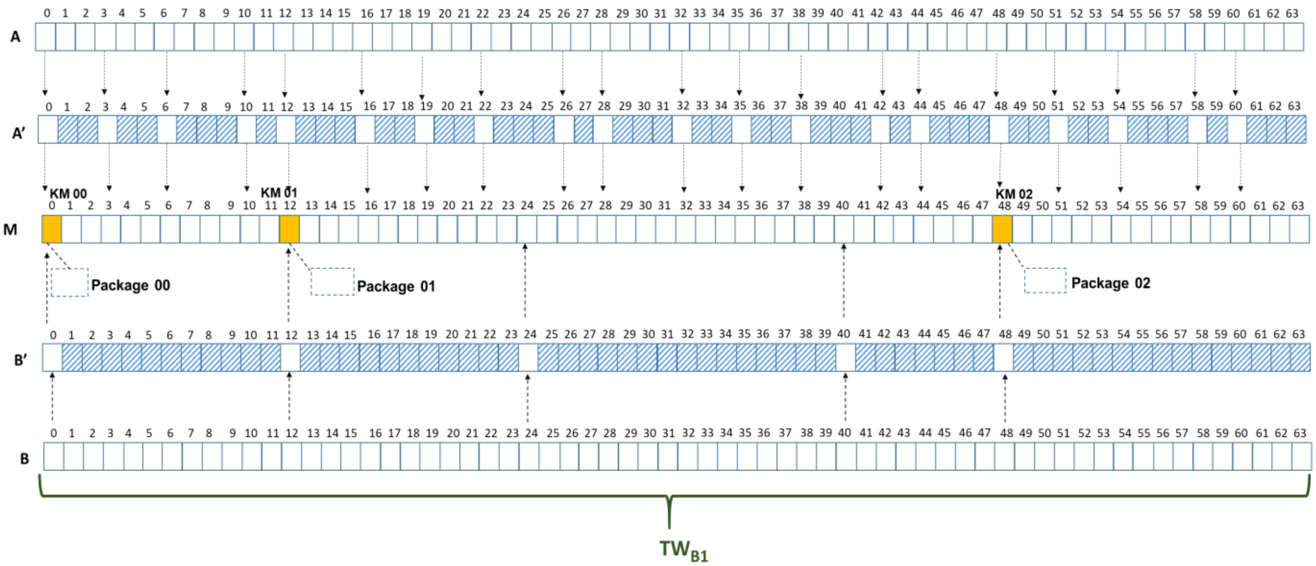


Figure 5-19. A snapshot in the moments without IU's.

In Figure 5-19 is presented a snapshot zooming in a TW_B with empty packages. This time, there is no information on any organization. In other words, there is no information being exchanged. If the sequence of empty KM happens, then the information exchange in that specific ERO it might be considered too fast for the operation. It has to be observed that this example reflects one part of the operation in which two organizations are already participating.

Therefore, most of the slots are void. Thus, the time interval may need to be shrunken. The rhythm becomes too slow when too many KMs in the bus M are blanks or the IUs in M are too sparse. If the information exchanged is too sparse in the operation line, it means that the operation pace is also slow, and the rhythm is set up too fast for that ERO pace.

Figure 5-20 presents another representation of the previous snapshot in a timeline with a duration of 33 periods in a given operations moment. This time, instead of the KM, it is detailed the organization A. Periods 1, 4, 7, 11, 13, 17, 20, 23, 27, and 29 above display four RPs in a rhythmized flow for organization A', and 33p displays an additional four slots in the snapshot. In other words, there are two sets of Son Clave with 32 periods and the first period of a third set.

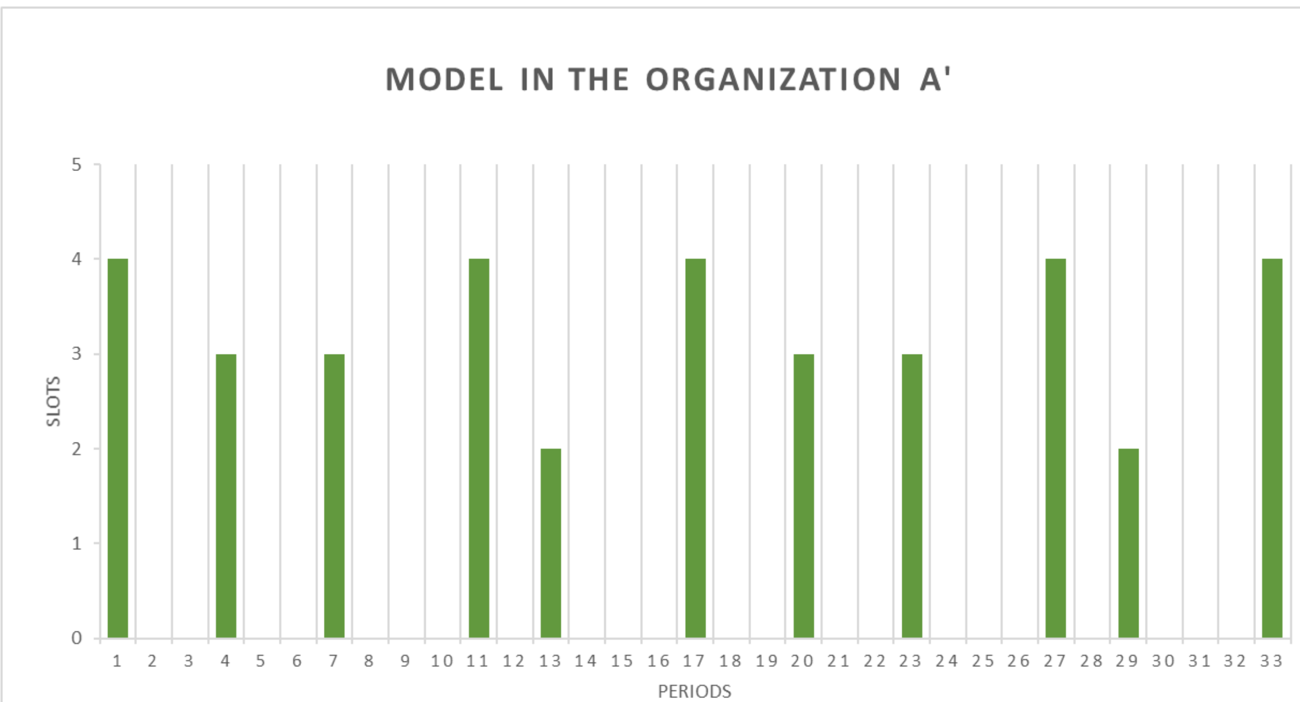


Figure 5-20. Operations flow in Organization A'.

Figure 5-21 represents a screenshot of the information been exchanged at some point. It is shown in this figure that there is a quantity of information that is able to be exchanged. In order to test the model correctness it was developed an algorithm implemented in GNU Octave, version 3.8.1. The suitability for an operation volume of information was also experimented. We understood that a pace might be considered too slow for the operation if there are slots available for exchange and are void. As stated, if the operation rhythm is too slow, it means that most of the bars are void. Therefore, the time interval might need to be shrunken. The functioning of the model presented in Figure 5-21 is too slow because there is only one IU, while 36 were expected until this exchange, as represented in the graph over time.

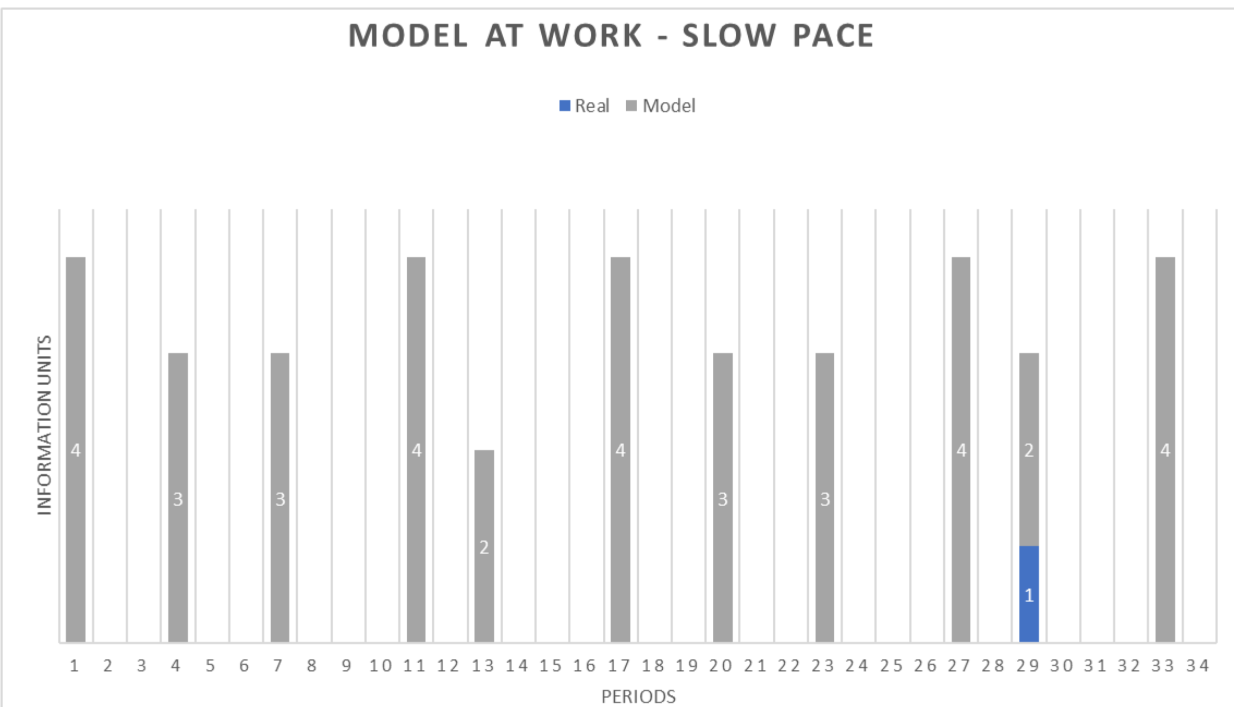


Figure 5-21. Graph of use at a slow pace.

On the other hand, for each organization, the rhythm might become too fast. This effect might when the IUs in the mediator bus are allocated far ahead in the rhythmized flow. Therefore, the pace can be enlarged following the same procedure described in Section 5.2.3. The fast situation can be seen in Figure 5-22, which displays a snapshot of the timeline in operation with two Son Clave sets plus the first part of a third set. However, there is one or more IUs to be sent that do not fit in the period. Thus, they will be displaced ahead and become a delay in the exchange.

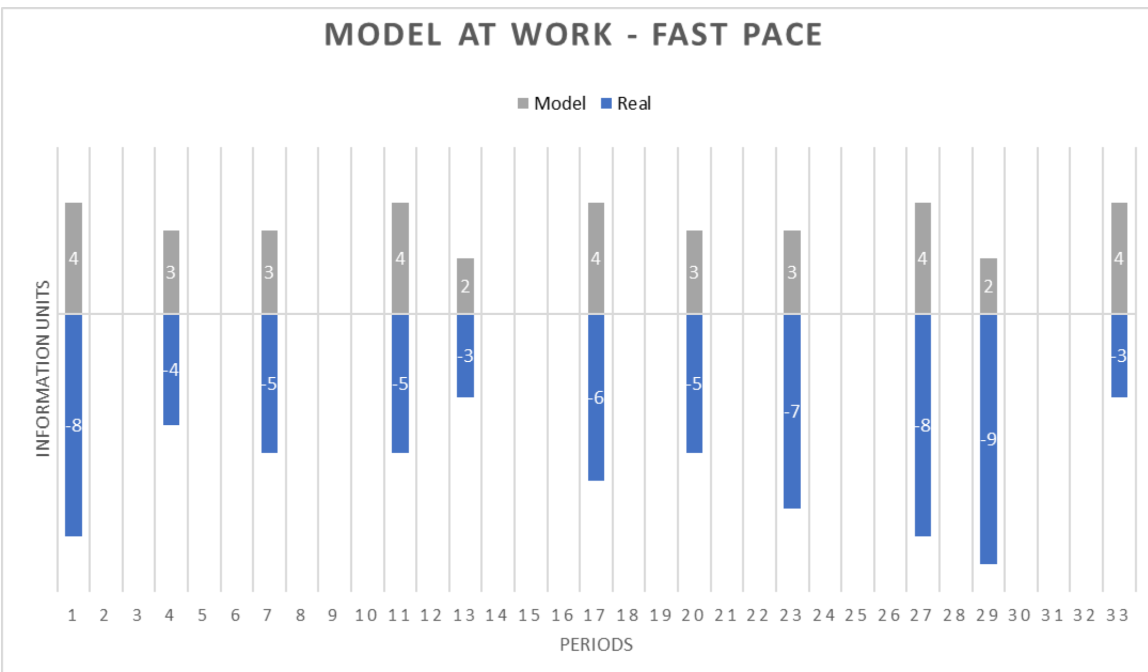


Figure 5-22. Graph of use at a fast pace.

The initial rhythm factor values one and four are heuristic values based on previous operations. In the insertion of a third organization, one must start with an estimated rhythm factor. In our findings, when adding aerial resources in the ERO, we would have an average of 180 IU for each IU of the slower organization. However, it has also been observed that organizations with faster tactical rhythms tend to exchange less operational information because they consolidate them. Therefore, the disparity in the rhythm factor may converge.

5.5 Rhythmic Model Characteristics and Discussion

The model was built following the basic properties of Son Clave stated in Sections 2.5 and 2.6. We used mainly the maximum evenness property, the oddity property, and the metrical dissonance. These properties cover most of the observed rhythm problems in information exchange.

The introduction of evenness of information exchange creates an expectation that increases the predictability around possible periods in which information is exchanged. Many events and actions are not predictable in an ERO. Even for those expected, the periods might vary largely. It is crucial to keep regularity because it not only tells emergency operation centers (EOC) when to anticipate the receipt of information but also indicates which organization is not sending information. That lack of information may be due to the specific information rhythm pattern of an organization or from field problems to communication or even IS issues.

In our model, as already explained, the information being exchanged, which represents a significant part of the information in the EOC environment, is mainly passive and or peripheral. If a large quantity of information is received at once, and nothing after a certain amount of time, that initial information might be lost. However, by applying our model in ERO, the IUs are spread to keep regularity. In addition, the information avalanche starts increases in predictability. Thus, by rhythmizing an organization's information flow, we try to use the maximum evenness property.

The rhythm oddity property prevents IUs exchanged from becoming overly predictable. Therefore, in an ERO, it is also essential to "break" the regularity of the exchange now and then. For example, in an EOC, too much regularity in presenting information can lead the operators to pay less attention to the information presented or even to dismiss the information entirely from certain sources. Thus, information that occurs in a different moment than expected or a sudden change tends to keep operators alert. For example, when information is received regularly and steadily, some tend to ignore it. Thus, changing times for the exchange of information might make the personnel at the EOC pay more attention to that information, as seen in the examples of visualization of peripheral information or even visualization of tracking routes. To the same purpose, the property of metrical dissonance is present not only in each organization rhythmized flow but also in the different periods of slots between the KMs in the Mediator Bus.

Some additional properties of the Son Clave were not envisioned to have an immediate application in the EOC. For example, shadow contour isomorphism, in which the shadows, a priori, is not used for exchange and do not have an immediate EOC application. Therefore, this property does not take part in the model.

We know that not only the Son Clave can be used as a Rhythm Pattern timeline. The six timelines discussed in Chapter 2 could also be used interchangeably, but as we have already mentioned, the Son Clave presents a theoretical uniqueness that makes it to be chosen for the model. In addition, much more sophisticated music timelines, as seen in gamelan Balinese and Indian talas, can be tested in the future. However, it was not the intention of this work to create feasible music, but a useful model for information exchanged in ERO.

5.6 Problems solved by the Model

In order to show how the model solves some problems, we choose a detected problem, the duplicated efforts, in which similar occurred in Serrana's Operation Mini-case and applied, exemplifying how the model helps in ERO for lack of synchronization and specifically, for duplicated efforts and missing leader. The model also helps with information overlap and different durations problems.

As presented in Chapter 4, synchronization problems are a set of problems that includes duplicated efforts and missing leader. Using examples that happened in the Serrana Operation, we show how the model application helps in the following ERO scenarios:

5.6.1 Duplicated efforts scenario

The 3rd Marine Infantry Battalion (3rd MInB) was delivering food and water in Olaria neighborhood. The 6st Military Firefighters Group (MFG) asked them to help a family that needs to be rescued. This request was answered by 3rd MInB. The family localization was in a hard place to reach, which took them some effort and a truck for debris removal. When they arrived at the place, the family have already been rescued. In the Jardinlândia neighborhood, the food distribution was not done because the 3rd MInB went to rescue a family.

In the other place of the state, the Local Civil Defense informed the COMFE that there was a need to rescue a family. The Army 21st Field Artillery Group (21st FAD) has the responsibility to rescued at Friburgo's municipality and received the request from the ComFE. The Army 21st FAD had some difficulty in reaching the place but rescued the family.

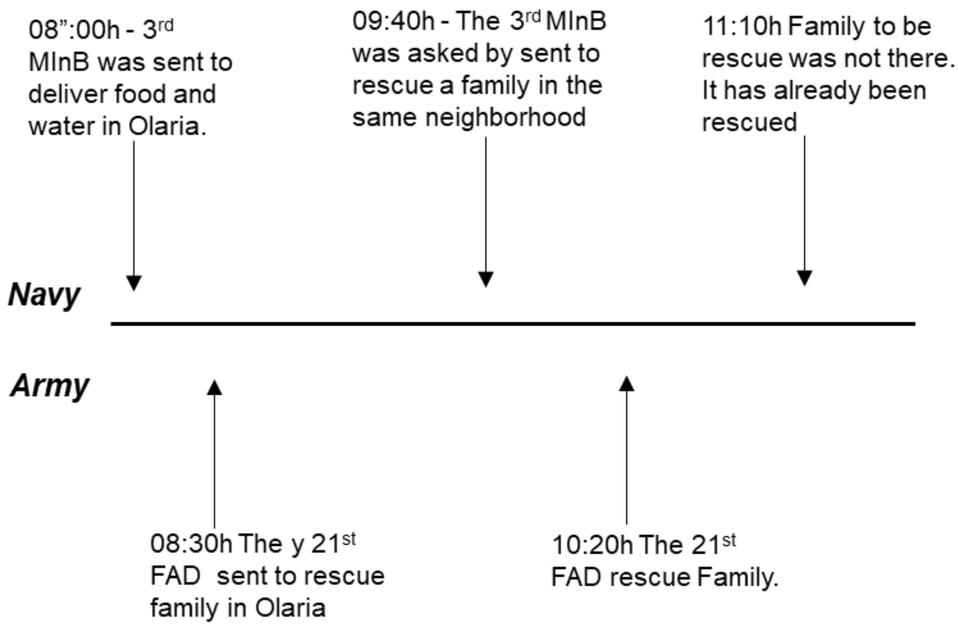


Figure 5-23. Example of missions in the timeline with duplication effort.

It is demonstrated in Figure 5-23, a scenario of duplication effort. The 3rd MInB went to rescue a family that has already been rescued. An unwanted effect is to postpone delivering food and water to the community in Jardinlândia.

In order to avoid the duplication of efforts presented in Figure 5-23 the model is used in this scenario and presented in Figure 5-24. In the last one, the IU starts with N for Navy messages and A for Army IUs. The code for specific military organizations was not applied to simplify the figure. By applying the model it can be seen that the last IU does not arrive because the action did not happen. The 3rd MInB was sent to deliver food at 08:00h, and this information is exchanged at 08:10 in M01 that is also the KM00. After receiving the firefighter's request to rescue a family, the 3rd MinB started to go but aborted the task since, in the M12, that is a KM 01, they were aware that another team was going to rescue them and abort its task. The IU N03 does not happen. Therefore, for any IU coming from N or A organizations that are exchanged before the KM 01, actions can be changed, and duplicated efforts avoided. By applying as presented in Figure 5-24, there will be time to deliver food and water at the Jardinlândia neighborhood.

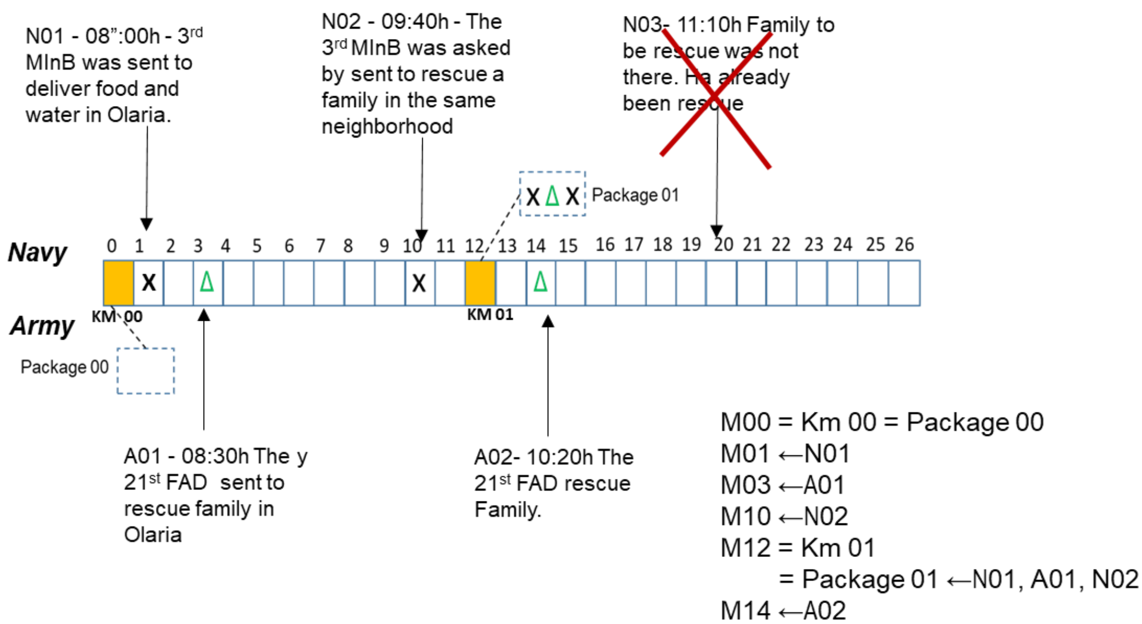


Figure 5-24. Example of missions in the timeline without duplication effort.

5.6.2 Missing Leader scenario

Getting the rhythm of the whole operations with key moments, shared by all the organizations involved, might provide a sense of presence for authorities who have the decision making power. By knowing these times, decision makers can make themselves available. For example, using the bridge scenario in Section 4.2, by getting the key moments of the operation, adding many organizations, it will be known moments in which all the organizations will be exchanging information and leaders might be asked to be available around that moment.

5.6.3 Information Overlap Scenario and Different Durations

Empirically it is shown that by applying our model, information updated at key moments will increase the chances that new information does not get lost. However, to the extent that the use of the model will avoid information loss was not measured in this work. Another benefit of the application our model is the use of limited characters to exchange information, ideally linked to other information like pictures, files, audios, and others.

The information exchange problems addressed by our model are consolidated in Table 5-2. As presented, this research specifically addressed types I, II and III of information exchange detailed in Chapter 3. We defined the key moments in information exchange for a specific branch and for the overall exchange itself. These key moments will arise from the rhythm that organizations already have and are often tacit. Therefore, we needed to make some inferences in pace and tempo.

Table 5-2. Types of problems solved by our model.

Categories of Problems	Description
Type I	Lack of synchronization
Type II	Different durations of an Information Unit
Type III	Temporal overlapping

For dealing with the Type I problem, that is this work encompasses Duplicated Efforts and Missing Leader scenarios, we created the KM that ensures the existence of moments for information exchange and some dynamic moments for synchronization. We also defined how to fit IU in the established rhythm for an operation. The RP's were defined to deal with the rhythmless flow of information, making them more organized from the perspective of the branch. We also defined the slots that will receive IU's. By doing that, the Type II problem was solved. The model also assures that information will not be missed by using packages in the model, thus addressing the Type III problem.

Although the model does not solve the problem types IV and V, we believe that the understanding and solution of problem types I, II, and III will support a future solution for types IV and V. We foresee some opened possibilities by this research that could be further explored without changing the model structure. For example, it might be possible to exchange information between Mediators. One could send information to a Mediator in the past time when doing simulation exercises with different temporal clocks. Moreover, adding thematic layers to the models' use by adding labels such as search and rescue, medical evacuation and treatment, logistics, and transportation, might be possible. The labels are interesting for understanding the rhythms in each of these subjects.

5.7 Research Methodology

One of the most accepted definitions of Design Science is "…a research paradigm in which a designer answers questions relevant to human problems via the creation of innovative artifacts, thereby contributing new knowledge to the body of scientific evidence" (Hevner and Chatterjee, 2010, p. 5). Research design started with Simon (1997) with the need to develop and achieve a specific desired situation.

Because of this, the primary outcome of this research is a conceptual model. In the research process, we also looked into modeling and simulation areas. That area uses a superposition methodology in order to build a conceptual model (Dahanayake & Thalheim, 2011). Design science research and modeling are considered closely related.

In this work, a methodology for DSR, mainly used in Information Technology, is built on three main components: the conceptual principals of DS, practical guidelines, and the process for executing and explaining the research. The principals come from the DSR definition of developing constructs, models, and instantiations (Hevner et al., 2004), or any artifact developed to solve a research problem. The guidelines include 1) design an artifact; 2) problem relevance, 3) design evaluation of utility, quality, and efficacy, 4) research contributions, 6) research rigor, designed as a search process, 7) and communicating research. It is a specific process to conduct the research, including its execution and explanation (Peffers et al., 2007).

In this work, the research process was designed to obey the DSR components mentioned earlier and explains the results. Therefore, the second phase was built over Peffers et al. (2007) processes and specific activities to conduct the research. The activities that compound this research process are compiled from Hevner et al. (2004), Takeda et al. (1990), (Nunamaker Jr et al., 1990), Eekels and Roozenburg (1991), Walls et al. (1992), and others.

In order to understand the rhythm problems in ERO and develop a conceptual model for helping exchange information between organizations with different rhythms, this research had two different phases, as presented in Figure 5-25. In the first phase, data were studied data from an ERO in Brazil, specifically from the 2011 Serrana Operation in Rio de Janeiro, Brazil. The qualitative data was analyzed thought document analysis. The qualitative data was also plotted in a graph in order to get a better understanding of the disaster.

Nevertheless, it was not enough to understand the problems with information exchange and data with the examples that were used and the information exchange problems that were mapped. Therefore, this first phase was exploratory, presenting a mini-study case and a document analysis to dive into the problems. From the rhythm perspective, it required modeling a way to accommodate the different rhythms in ERO, which lead to a second research phase.

For the second phase, developing the conceptual model, the Design Science approach was followed. The second phase followed the DSR framework. Although the framework research is presented sequentially, it is not determined that the following work is sequential (Johannesson & Perjons, 2014). In fact, the activities are logically related to the results achieved during the research.

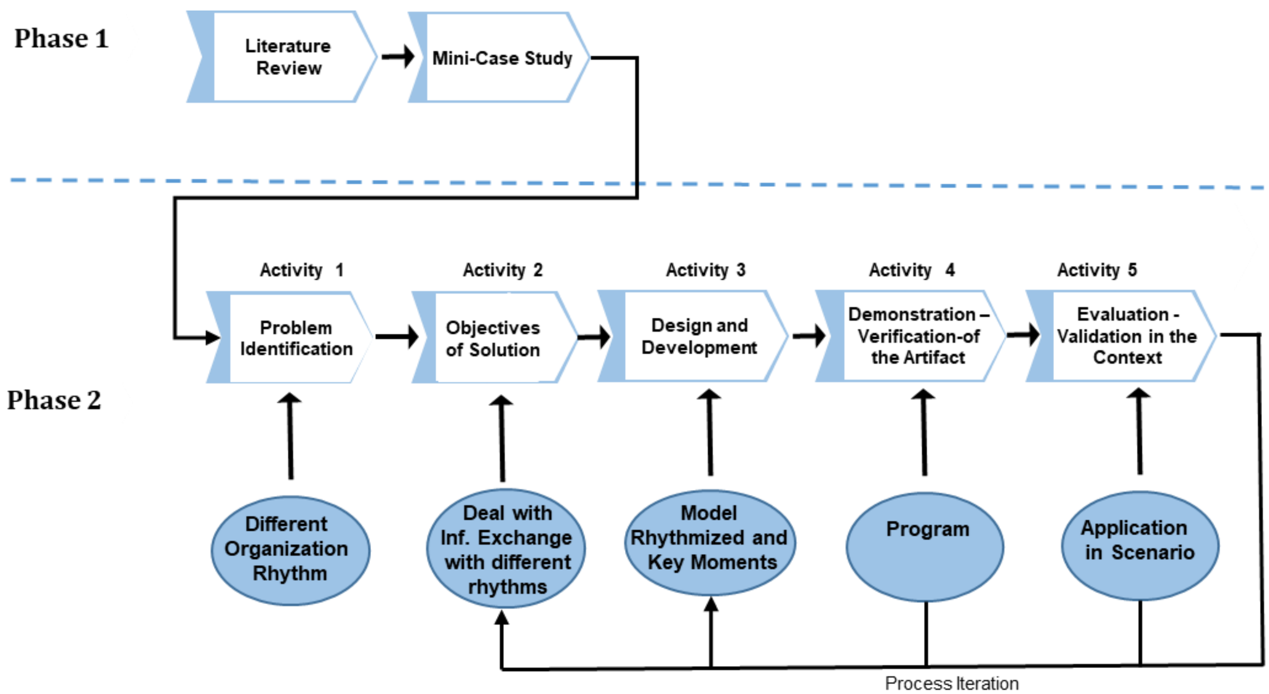


Figure 5-25. The research design process followed

The need for a model for information exchange between organizations with different rhythm was already established. In Figure 5-25, we demonstrate that our research process about the information exchange problems follows a process consistent with DSR. Phase 1 was exploratory, and Phase 2 use modeling in DSRM adapted from Peffers et al. (2007). The artifact generated in this work is a conceptual model, and its need is already demonstrated in Chapter 3. We are using some concepts of conceptual modeling, as mentioned as well:

1) Problem Identification – In DSR, explaining the problem's importance and justify the solution value is essential to perform research. In this work, from studying joint operations and specific operations that support emergence response, it was found that the differences in rhythm between organizations play a role in those operations and in the time in which organizations exchange information. In such a busy environment as an ERO, coordination problems, along with rhythm differences, contribute to the problems detailed in the mini-study case presented in Chapter 4. The problems were mapped in Phase 1 in this research. Harmonizing rhythms is crucial because it might reduce the lack of information, the lack of synchronization, and information overlap. Solving these problems reduce undesired, uncoordinated actions in these operations, saving resources, and possibly lives.

2) Solution Objectives – The solution's objectives for the problem definition are explained here. A conceptual model, with little or no knowledge about rhythm in ERO, is the feasible solution. The conceptual model has to be able to deal with information exchange between organizations with different rhythms. It was found that imposed rhythms tend not to be followed. Therefore, the model has to harmonize the rhythms into one rhythm for the whole operation. However, the model should not significantly change the original rhythm of each organization. Depending on the organizations that take part in an ERO, the model has to be parametrized to fit better. Thus, the aim of this work is the rhythmization of the messages exchanged between the armed forces allowing for better situation awareness and resource utilization. This work aims to reduce the transitory situation by organizing information.

3) Design and Develop – In order to develop our model, we had found inspiration in an area that deals with different rhythms and are able to harmonize them. In addition, although the theory deals with complex rhythms, the subjects must be able to be mapped onto a feasible model within the context of the problems. The inspiration comes from music theory, specifically from polyrhythms. We reviewed the military acting in emergency response, organizational theory, and music theory. Thus, from the literature reviewed and the lack of models that support the needs, we formed a theoretical framework that culminated in the model. More details are explained in Chapter 5. An iterative process was used to develop a valid model.

4) Demonstration – It must be demonstrated that the model solves one or more instances of the problem described above. For conceptual models, this activity means that the correction of the model is verified. Operational verification is made through an algorithm and its implementation described in Section 5.2.7. The running model shows that once each organization gets its information rhythmized, it creates compatible rhythms.

5) Evaluation – This activity observes how the model solves the problem. It is related to validation. Acquiring data from the real world is hard. In our case, we had some data, but it was not of a quality that was useful in the modeling. Although the procedures for conceptual modeling were followed as described in Figure 5.23, as are many models in these circumstances, this validation lacks a high degree of confidence. Thus, for validation, we use the subjective approach in non-observable systems by exploring model behavior that uses one type of operational validity presented by

Sargent (2011, p.189). The use of visual drawings is also a helpful tool for validation. It is interesting to go through the model while explaining each element and its behavior (Robinson, 2008). In this research, we explain the logic behind the steps, as well as its development to validate our model. Our evaluation is based on empirical evidence using scenarios found in real operations and showing that applying the model achieves results that improve the effectiveness of an ERO.

6 Conclusions

During the accomplishment of this work, it was explored the problem of information exchange with different rhythms between armed forces while acting in Emergency Response Operations (ERO) for supporting Civil Defense in response to natural disasters. Emergency responses can be linked to military operations and time-sensitive business activities. In this research, it was described in detail the importance of that exchange timely and the need to deals with different rhythms.

Musical rhythm is embedded and surrounded by music elements. Similarly, rhythm in ERO is an intrinsic element that cannot really be separated from the whole operation. To the best of our knowledge, there was a gap in research for dealing with different organization rhythms. A model was designed to cover these needs.

6.1 Study Contributions

In this thesis, we showed that the existing problem of different rhythms for the exchange of information in organizations could be minimized by applying the framework of musical rhythms. To the best of our knowledge, how the information rhythm of the organizations affects the information exchange, and the understanding of the whole operation was not explored prior to this research. We explained that the different rhythms are a problem in those operations and can be minimized by applying our musical rhythms model.

We looked into problems in those operations using a mini-case study about Serrana Operation. This temporal problems mapped and our modeling, to the best our knowledge, is an innovative way to think about timely data. In addition, many questions have arisen from this work. Aside from the academic contributions gained from the research model itself, it is expected that one would better learn how to deal with the varied viewpoints on the important dimension as the timeframe for information exchange.

We showed that Music Theory and specifically Polyrhythm is a feasible abstraction for information exchange, thus helping to build the constructs, and create operations that can be used for information exchange. Our approach proposed is a set of simple solutions for a complex problem that was broken down into smaller pieces, and solved in atomic operations.

We can use the model to increase the SA in the EOCs because the model can be used to allow sharing a temporal view. This vision will work as a whole song, in which the different rhythms are presented in harmony. Our conceptual model supports the development of a software artifact that acts as a hub. This implementation will be done on service architecture.

It has been shown that our approach is generic and extensible enough to cover a variety of temporal problems when exchanging information. The detailed explanation of our abstractions has shown, throughout scenarios that they are valid. The use of the abstractions presented here, and their operations, are promising in their use to support the information exchange between organizations with different rhythms.

6.2 Study Limitations

In order to be transparent regarding the methods and applicability of this dissertation's model, we will describe three limitations of the model. These limitations commonly occur in conceptual simulation model design (Robinson, 2008) and do not diminish the contributions of this dissertation. Instead, they highlight opportunities for future research that can help to refine further and strengthen the conceptual framework and its use.

Acquiring data from the real world is hard. In our case, we had the data, but it was not in a quality that could be able to be useful in the modeling. Although the procedures for conceptual modeling were followed as preconized by Robinson (Robinson, 2008b), as many models in these circumstances, this validation lacks a high degree of confidence.

The main limitation of this work is that we took a relaxed adaptation of polyrhythms and entrainment concepts. Even if with a successful implementation of this model, we expect that most officers in the Armed Forces, belonging to the C2 area, must be individually able to make timely decisions. Therefore, the model does not solve problems of gaps in knowledge or lapses in judgment. In addition, the more organizations involved, the fewer key moments, and that maximum limit should not be greater than the check-in periods. These KM help the EOC to process all the arriving information.

We also have to remember that we focused on the “when” part of the problem described in chapter 2. Thus, questions of “what”, “why”, “how” and “where” are not addressed here. In other words, the model proposed is focused on the “when” part of the information exchange.

6.3 Future Works

This study provides a preliminary foundation for using music as a framework, such as presented in our model. However, there is still much more research needed to fully explore the problem of information exchange between organizations with different rhythms. We suggest two areas of future work:

(a) Application of this model as a layer in C2 systems: To be used in complex events analysis or simulation training in academic venues, such as to be used for training officers for decision making in operations. Applying this model as another layer in complex events, we could also try tracking specific events. For example, we suspect that helicopter squadrons and infantry platoons, in the same branch, have different rhythms. If it is confirmed, we could apply this model to understand the differences. In addition, our model might be investigated in civil organizations and NGO's that acts and natural disaster relief.

(b) Solving types IV and V problems: For the type IV, we have semantic problems, such as messages that are referred to other temporalities, such as "the platoon will be there for one week". For the type V, we have the IUs exchange between two or more systems that have different simulated times or pace, such as happens in joint computer simulation exercises. Therefore, in future works, we could consider the relations between the future and past in a timeline. For example, we have different operation simulation systems when working as a federation. These systems sometimes have a different march of time. These differences can be seen in exercises in NATO simulation. In that scenario, wall clock synchronization is not possible, and most of the time, it is hard to send a message to the future, which is the time of another simulator.

Given the importance of exchanging information for organizations with different rhythms, we see the continuity of this research in other areas. For example, we also expect that this research might be used not only for the information exchange itself but also for the visualization of this information. For example, although there is some indication of a relationship between acoustic temporal perspective and visual temporal perspective (de Graaf et al., 2013; Spaak et al., 2014), the significant relationship is not well established yet, and neither its use in EOC environments.

6.4 Closing Remarks

We have presented the building blocks for the rhythmic information exchange between organizations with different rhythms. We used a Design Science Research approach to provide a conceptual model. Our model is general enough to allow other uses. For example, it could be used as a starting point to define rhythms to other organizations that are not necessarily related to ERO. In addition, it is important to observe that we developed a foundation for the use of rhythm in music theory as a framework for future research in information exchange. Furthermore, it is essential to note that in this sense, the research will not end with this dissertation; instead, it creates a solid base for research to be developed.

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WORK EXPERIENCE

- Current – Science, Technology and Innovation Coordinator of the Blue Amazon Management System (SisGAAz) at the at Brazilian Navy – DGePM
- Maritime Data Integration to Support for Situation Awareness (MIND) with South Caxias University (UCS) and US Navy
- Research Project Manager of Development Process Quality Software improvement with automated tests in partnership with Federal Fluminense University (UFF), 2013
- Software development Project Manager of Operational Intelligence System at the Center of Naval Systems Analysis; 2012
- Research Project Manager of Geocoder Module (GEONAV) from Monitor Blue Amazon and Merchant Ships (MAZFN) sponsored by FINEP, 2012
- Part of the team responsible for implementing Communications Management System for the Joint Atlantic Operation 2008;
- Implementation of the Logistics Decision Support System at the Brazilian Naval Surface Force; 2008
- Organizational restructuring at the Brazilian Navy Data Centre and ComForSup; 2007
- Requirements of the Brazilian Navy's Personnel Movement System – Squadron Model; 2006

ACADEMIC

- GRADUATE
    - PhD in Information Science and Technology Program at Penn State University, 2020
    - M.Sc. in Computer and Systems Engineering at Federal University of Rio de Janeiro, 2008
- UNDERGRADUATE
    - System Analysis, BS, Salgado de Oliveira University, RJ. - 1998;
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- Lecture - Data Science II – La Salle University – 2020
- Lecture - Digital Inclusion classes – Center for Naval Systems Analyses – 2009

- Talk – Artificial Intelligence in the Brazilian Navy – 2020
- Talk - Federal Fluminense University (UFF) - 2018 – Organizational Rhythms and Information Systems - 2018
- Talk - Caxias do Sul University (UCS), The Difference in Organizational Rhythms and their Influence on Information Systems, XIV Brazilian Information Systems Symposium – 2018

MOST RECENT PUBLICATION

Pessôa, L., Ferreira, R., LAGE, C., & Almeida, A. (2018). Impact assessment of decision-making policy: a proposal for using Fitradeoff. Brazilian Meeting of Production Engineering (ENEGEP, Alagoas, Brazil).